RULES

Books and periodicals may be used in the Society rooms by members and friends.

Members may borrow books for home use—with the exceptions noted below—but no one shall have more than four books at any time, or keep any book more than two weeks.

Volumes belonging to a set—such as volumes of bound periodicals and of proceedings or transactions of societies—and such other books as the Board of Government may designate, may be taken from the rooms for a limited time only, by special arrangement with the attendant. They shall be subject to recall at any time.

There shall be no immediate renewal of any book on its return to the library.

A member borrowing a book shall at that time give a receipt therefor.

A fine of one cent per day per volume shall be charged for over-time, and must be paid before the delinquent can take any more books.

Hand books, indexes, current numbers or unbound files of periodicals, books belonging to the Clemens Herschel Special Library, and new books not yet placed on the regular shelves must not be taken from the rooms.

Books of unusual value are marked with a star (*), and must not be taken from the rooms, except by written permission from the Librarian, to be filed by the attendant.

Any person mutilating or losing a book shall pay for the damage, or replace the book.

Any one who violates the above rules may, upon written request from the Librarian to the Board of Government, be debarred from the privileges of the library for such time, not less than three months, as the Board of Government may determine.

(Revised June 16, 1915.)

JOURNAL

OF THE

New England Water Works

ASSOCIATION.

VOLUME VII.

September, 1892 to June, 1893.

PUBLISHED BY

BOARD OF EDITORS.

Junior Editor's Office, New London, Conn.

INDEX.

INDEX.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. VII. September, 1892. No. 1.

This Association, as a Body, is not responsible for the statements or opinions of any of its members.

PROCEEDINGS OF THE ELEVENTH ANNUAL CONVENTION,

Holyoke, Mass., June 8, 9 and 10, 1892.

The sessions of the Eleventh Annual Convention of the Association were held in Hamilton Hall, Holyoke, Mass., on Wednesday afternoon and evening, June 8th, and on Thursday morning and evening, June 9th. The headquarters of the Association were at the Hotel Hamilton.

AFTERNOON SESSION.

WEDNESDAY, June 8, 1892.

The convention was called to order by President Holden, who spoke as follows:

It is a pleasant duty to welcome so many old acquaintances here today in this busy manufacturing city. When it was decided that we should hold our meeting at Holyoke there were grave fears that we should have but a limited attendance from the eastern section of New England, but the present appearance indicates that *every* section will be well represented. I now have the pleasure of presenting to you the Hon. Jeremiah F. Sullivan, mayor of the city of Holyoke. (Applause.)

ADDRESS OF WELCOME BY MAYOR SULLIVAN.

Gentlemen of the New England Water Works Association:—It becomes my pleasant duty to welcome you to Holyoke, and I am pleased that you have chosen our city as the place for holding your convention for the year 1892, and I trust that the result of your deliberations here may be of advantage to the people at large, and that your stay among us may be a source of pleasure to yourselves. We also feel honored by the presence here of your honorable body.

It is claimed, and I think generally conceded, that in the department of engineering, America stands at the head of the world. The grasp of the American engineer seems to be on a scale commensurate with the great extent of the country. Engineering works greater in number and upon a more extensive scale have been entered upon and executed here than in any other part of the world, and your profession has done more than any other to develop the resources of the country. We hope that you will continue to hold and strengthen your position at the head.

As the states, cities and towns increase in population, the question of water supply becomes of great importance. Massachusetts in particular has been called the state of cities, and the question is perhaps of more importance here than in any of the other New England states, though it is of much importance everywhere.

The question of water supply comes very near home to us here in Holyoke, because a great water power is the foundation of our city. The question is also interesting to us in another aspect—how to secure sufficient water for domestic purposes. We have already appropriated all the water from available streams and ponds, and the growth of our city requires us to seek further facilities for water supply. How best to utilize for the benefit of man the waters of adjacent brooks, rivers and ponds is a useful and interesting study, and the discussions of your association must be of great benefit in this respect. We shall be pleased if our city shall furnish you with a favorable field for your labors and discussions.

Without wishing to take up any more of your valuable time, I again heartily welcome you to Holyoke. (Applause.)

The President. Mr. Mayor, in behalf of the New England Water Works Association I thank you most heartily for the welcome you have given us, and extend an invitation to you or any of the citizens of Holyoke to attend at any of our sessions.

The regular order of business was taken up, the reading of the records of the last meeting being dispensed with.

ELECTION OF NEW MEMBERS.

The Secretary presented the following list of applicants for membership, all of which had been properly endorsed, approved by the executive committee, and recommended to the Association for election :

RESIDENT ACTIVE MEMBERS.

George K. Crandall, Assistant Engineer, New London, Conn.
S. G. Stoddard, Jr., Engineer Hydraulic Co., Bridgeport, Conn.
Robert J. Thomas, Superintendent, Lowell, Mass.
Joseph B. Rider, Civil Engineer, South Norwalk, Conn.
Luther C. Wright, Superintendent, Northampton, Mass.
Waldo E. Rawson, Superintendent, Uxbridge, Mass.

NON-RESIDENT ACTIVE.

G. H. Benzenberg, City Engineer, Milwaukee, Wis.

Hugh F. Doran, Superintendent, Port Huron, Mich.

E. L. Dunbar, Superintendent, Bay City, Mich.

John Erwin, Secretary and Treasurer, Middleton Water Supply Co., Bridgetown, Nova Scotia.

D. W. French, Superintendent, Hackensack High Service Water Works, Weehawken, N. J.

James S. Haring, Civil Engineer, Fort Madison, Iowa.

William R. Hill, Chief Engineer, Syracuse, N. Y.

Jacob L. Kuehn, Superintendent, York, Penn.

R. G. E. Leckie, Constructing Engineer, Middleton, Nova Scotia.

Thomas H. McLaughlin, Superintendent, Texarkana, Ark.

George W. Wright, Chief Engineer, Norfolk, Va.

J. W. Ridpath, Secretary and Manager, Jenkintown, Pa.

George H. Robertson, Superintendent, Yarmouth, Nova Scotia.

L. J. Wagner, Superintendent, Rome, Ga.

John Thomson, Hydraulic Engineer, 408 Temple Court, New York city.

Everett L. Abbott, Civil Engineer, 708 8th Avenue, New York city.

ASSOCIATE MEMBERSHIP.

Crosby Steam Gage and Valve Co., Geo. H. Eager, Treasurer, Boston, Mass.

Meter Register Co., 52 Illinois St., Chicago, Ill.

G. H. Moore, Water Filters, Norwich, Conn.

The Hydraulic Construction Co., Wm. d'H. Washington, Manager, 145 Broadway, New York city.

On motion of Mr. Brackett the Secretary was authorized and directed to cast the ballot of the Association in behalf of the nominees whose names have been read, and they were declared elected.

The President then delivered his annual address.

ADDRESS OF PRESIDENT HOLDEN.

Gentlemen of the New England Water Works Association:—We are now for the eleventh time assembled together in annual convention, and a decade of years has passed over our heads, since a small company of us assembled at Young's Hotel, in Boston, and organized the New England Water Works Association. At our first annual meeting we had a membership of 25, eighteen of whom are still with us. Today we have 312 Active, 74 Associate and 5 Honorary members, making a total membership roll of 391. Our organization from the beginning has shown a steady increase, and today I am happy to report that our Treasurer has a balance on hand of $1,908.28. The usual number of meetings have been held during the past year and the attendance has been good, notwithstanding that the prevailing distemper last winter kept many of our most regular attendants confined to their homes. Last September we accepted an invitation from the Standard Thermometer Co. to visit their manufactory at Peabody, and were made

conversant with their electrical appliances for indicating the height of water in reservoirs and stand pipes, together with many other electrical appliances which are manufactured at their factory. By having the fall meeting held in some central locality, it serves to draw together more members than a long pleasure and sight seeing excursion can do. There were several very interesting and instructive papers presented at the winter meetings, particularly the paper by Mr. Forbes on Algæ and Infusoria, the paper by Mr. Stearns on the selection of sources of water supply, and the illustrated description of the East Jersey Co.'s new water supply for the city of Newark, by Mr. Shirreffs. The study of Algæ and vegetable growths in our streams, ponds and reservoirs should interest every Superintendent in the country, and we as an Association should act in conjunction with the Boards of Health from each state, to endeavor to procure such legislation as is necessary to prevent the further contamination of our brooks and rivers by sewage and factory refuse. Within a few years the theory has been advanced that disease germs are carried for long distances in our running streams. This has already caused the water and ice supply of several of our large cities to be looked upon with disfavor, and may in time seriously affect one of the largest winter industries of Eastern New England, and if this is really as bad as has been represented, our Association ought to educate itself still farther on this subject. It is a source of gratification to know that we have as members of our Association, men who are devoting a large portion of their time to the study of these problems, which are now brought to our attention, and while we as Superintendents are not expected to all be conversant with the laws of Chemistry and Biology, we have the satisfaction of knowing that right here in our New England Association we can get the best advice in the country upon all matters pertaining to water supply and purification.

Among other matters which will be brought to your attention will be the selection of a place for our next annual meeting. Since our organization, we have held our annual meetings in eleven different cities, viz :—Boston, Worcester, Lowell, Springfield, New Bedford, Manchester, Providence, Fall River, Portland, Hartford and Holyoke, and our Association is now so large in membership that I question whether there are in New England many other places that can give us the necessary accommodation for holding a three days' session. Of the 325 Water Works in New England 102 are represented in this Association, and 60 of these are located within 50 miles, or less than two hours ride from Boston. There are forty-nine works within 50 miles of Boston that are not represented in this Association, and it appears to me that the greatest benefits can be received by having our meetings held where we can draw together the largest number of members.

Another suggestion which I wish to offer is in regard to a change of the time for holding the annual meeting. We are all aware that the month of June, although the most beautiful month in the year, for us here in New England it is also the busiest. Work such as ours can be done more economically now than late in the season, and many of the members who

would like to join us in these meetings are kept away on account of responsibilities which they cannot intrust to any one else, and if we could resolve one of the other quarterly meetings into a three days' session during which time we could attend strictly to business, then the June meeting might be reserved for either sight seeing or gathering information from any of our Associate members, who might invite us to inspect their manufactories or to show us the working of any novelties or standard articles.

The matter of securing permanent headquarters which was brought to your attention last year by President Noyes, is to be considered by a committee appointed for that purpose. Our finances may not be in condition to warrant this inovation just at present, but I trust that the time is not far distant, when we can afford to have good quarters, centrally located, and with a permanent secretary that will devote his whole time to Association business. He could compile all the reports from the different water departments throughout the country, and also collect all other information relating to Water Works, together with making drawings and blue prints of designs and Water Works appurtenances, and by so doing we might in a short time get together the most valuable Water Works library in the world. Our Associate members also could keep a permanent exhibit there, and would soon find that this was the most satisfactory way of placing their goods before the market.

At this time I wish to impress upon the members of this Association the importance of preserving our printed records of proceedings, together with the journals, by binding them in some durable form. Several of the back numbers are already out of print, and if those of you who now have them, will take the trouble to get them bound, you will find them now more valuable for reference on matters relating to Water Works, than any other work that is published in this country.

It can be hardly expected with an Association numerically as large as ours, that a year could pass by without the hand of death making inroads upon our membership. This year it becomes my sad duty to report the loss of two of our number, James Davidson, Superintendent of Central City, Colorado, and Samuel B. Leach, Civil Engineer of Tarrytown, New York. Both had been connected with this Association about three years, and had their lives been spared, would doubtless have proved valuable members.

In conclusion I wish to return my sincere thanks to all who have so ably assisted me in making every meeting of this Association one of interest. With the continued efforts of such officers as our present Secretary and Board of Editors, the New England Water Works Association is bound to prosper. (Applause.)

I have a painful duty to perform now in the announcement of the death of one of our oldest members, Robert M. Gow, late Superintendent of the Medford Water Works. I only heard of his death about an hour ago. Mr. Gow was one of the organizers of our Association, and was a man of large experience in everything pertaining to Water Works, and was a regular attendant at our annual meetings.

We will now hear the Secretary's report.

ANNUAL REPORT OF THE SECRETARY.

NEW ENGLAND WATER WORKS ASSOCIATION,
OFFICE OF THE SECRETARY,
NEW BEDFORD, MASS., June 1st, 1892.

TO THE MEMBERS OF THE NEW ENGLAND WATER WORKS ASSOCIATION :

Gentlemen—Your Secretary herewith presents his report for the year ending May 31st, 1892 :

On June 1st, 1891, the membership of this Association was as follows, viz :

Active members	281
Honorary members	5
Associate members	74
Total	360

During the year there has been a loss of thirty-one members from the following stated causes :

Resignations	21
Deceased	3
Suspended for non-payment of dues	7

Thirty-six applications for membership have been presented for your consideration, all of which have received favorable action.

The membership at this date is—

Active members	290
Honorary members	5
Associate members	70
Total	365

And the net gain for the year has been only 5 members.

Your Secretary has made 433 collections, which may thus be itemized :

From advertisements	$1,350.00
" initiation fees	203.00
" dues	1,193.00
" sale of transactions	94.27
Total	$2,840.27

All of which has been paid to the Treasurer.

Respectfully submitted,

R. C. P. COGGESHALL, Secretary.

On motion of Mr. Richards, the report was accepted and ordered printed.

Mr. Nevons, the Treasurer, then submitted his annual report.

ANNUAL REPORT OF THE TREASURER.

Mr. President and Gentlemen: I herewith submit my report as Treasurer of the New England Water Works Association for the year ending June 7th, 1892:

HIRAM NEVONS, TREAS., IN ACCOUNT WITH THE NEW ENGLAND WATER WORKS ASSOCIATION.

1891.	DR.	
June 23	To balance on hand	$2,238.57
July 23	" Interest paid Treas. by Camb. Savings Bank	6.12
Oct. 13	" payment by R. C. P. Coggeshall	1,200.00
Dec. 19	" " " " "	800.00
1892.		
June 1	" " " " "	840.27
	Accrued interest Cambridge Savings bank	2.12
	Accrued Interest Cambridgeport Savings bank	99.74
		$5,186.82

1891.		CR.	
June 23	By payment to	Rockwell & Churchill	$288.02
" "	" "	Francis L. Pratt	55.95
" "	" "	Charles H. Stacy	1.77
" "	" "	L. Barker & Co	6.00
" "	" "	Julius A. Kellogg	5.00
" "	" "	Putnam Phalanx	60.00
" "	" "	S. N. Benedict	50.00
" "	" "	Robert Allyn	30.25
" 30	" "	W. Rogers & Co	134.00
Aug. 19	" "	Heliotype Print Co	1.25
Sept. 29	" "	W. H. Richards	96.32
" "	" "	Heliotype Print Co	30.00
" "	" "	The Day Pub. Co	212.65
Oct. 27	" "	George E. Starr	4.50
Dec. 1	" "	R. C. P. Coggeshall	250.00
" "	" "	" "	166.78
" "	" "	Mercury Pub. Co	116.81
" 9	" "	Hartshorn's Orchestra	20.00
" "	" "	J. R. Whipple	11.50
" 18	" "	The Day Pub. Co	124.15
" 21	" "	W. H. Richards	99.99
1892.			
Jan. 23	" "	Robt. W. Taber	2.85
" "	" "	J. R. Whipple	12.00
" "	" "	Hartshorn's Orchestra	20.00
		Amount carried forward	$1,799.79

	Amount brought forward	$1,799.79
Jan. 23	" " J. W. Black & Co	14.10
" "	" " Bacon & Burpee	29.50
Feb. 9	" " John W. Weston	3.70
" 12	" " Hartshorn's Orchestra	20.00
" "	" " J. R. Whipple	11.50
Mch. 12	" " W. H. Richards	98.82
" "	" " Hartshorn's Orchestra	20.00
" "	" " J. R. Whipple	15.50
" 21	" " The Day Pub. Co	208.20
" "	" " Bacon & Burpee	52.50
" 30	" " Heliotype Print Co	32.50
Apr. 4	" " Reuben Shirreffs	36.00
" 12	" " Frank L. Fuller	6.00
May 11	" " Heliotype Print Co	22.50
" 27	" " Dexter Brackett	10.78
June 2	" " W. H. Richards	97.97
" "	" " Edwin Dews	8.25
" "	" " R. C. P. Coggeshall	250.00
" "	" " " "	124 68
" "	" " Mercury Pub. Co	141.75
" "	" " The Day Pub. Co	274.50
	Balance on hand National City bank $306 42	
	Camb. Savings bank $500.00	
	Int. to Jan. 28, '92 .... 2.12— 502.12	
	Cambridgeport Savings bank 1,000 00	
	Int. to Jan.20. '92 .... 99.74—1,099.74	1,908.28
		$5,186.82

HIRAM NEVONS, Treasurer.

Mr. Nevons. I wish to say further, in explanation of the balance, $1,908.28, that there were certain bills which have been paid this year which should have been paid and rendered in last year's account. The report shows an apparent loss, whereas, if those bills had been paid last year as they should have been, the report would show a gain.

The President. I believe there are no outstanding debts now.

Mr. Nevons. I know of but one small one. There is nothing that should rightly come into this year.

On motion of Mr. Brackett, the report was accepted and ordered to be printed.

The Secretary read a communication from Mr. George A. Ellis enclosing a paper entitled, "Two Methods of Obtaining Fire Protection by Direct High Pressure from Water Works Pumps in Combined Pumping and Reservoir or Stand Pipe Systems."

REPORT OF COMMITTEE ON BADGES.

The President. I will call upon Mr. Brackett, chairman of the special committee appointed at the last convention to consider the question of a badge for the members of the Association, to present the report of that committee.

Mr. Brackett presented the following report :

To the Members of the New England Water Works Association :

Gentlemen :—At the last annual convention of this Association, the undersigned were appointed to consider and report to the Association at some subsequent meeting upon the question of a badge for the Association.

The subject has been agitated to a greater or less extent for some time and it appears to your committee that some distinctive badge should be worn by the Active and Associate members of the Association, particularly at the annual conventions.

For a number of years it has been the custom to furnish each member attending the convention with a small bow of red, white or blue ribbon which has been a sufficiently distinctive badge but which has had no particular applicability to the objects of our Association and is not of a permanent character.

A design has been obtained and is herewith submitted with the recommendation that it be adopted as the permanent and official badge of the Association. The badge as proposed will be in the form of a separable button about five-eighths of an inch in diameter, bearing on its face a gold fountain upon a ground of blue or white enamel, encircled by the words New England Water Works Association in gold letters, the front of the button to be of gold and the back of gold plate. The cost of these buttons will be about 75 cents each.

A button of similar design, but of cheaper material and workmanship can be obtained for twelve dollars a gross or about eight cents each, but your committee does not recommend its use.

It appears to your committee to be very desirable that every person attending the annual convention should be provided with a badge designating whether they are Active members, Associate members or guests, and as it is probable that the permanent badge will not be universally worn, we recommend that the use of the present ribbon badges be continued in connection with the permanent badge.

Respectfully Submitted,

DEXTER BRACKETT,
F. W. WHITLOCK,
WM. R. BILLINGS.

Mr. Richards. It has always seemed to me desirable that we have a distinctive badge, and I heartily concur with the report of the committee. I move that the report be accepted, and that the Secretary be instructed to procure the necessary badges as recommended by the committee. Adopted.

The committee on "Uniformity in the preparation of the Annual Report" were given further time.

The Secretary then read Mr. Ellis' paper on Fire Protection.

The President called upon Mr. Garrett to open the discussion upon Topic 1, "The Proper Coating of Cast Iron Pipe," and he was followed by Mr. Brackett.

Mr. Byron I. Cook then read a paper in which he detailed the circumstances attending the detection of a waste of water on the Woonsocket, R. I., works ; and Mr. Walker of Manchester caused a little laughter by his efforts to find out the proper charge to be made against a man who was detected in stealing water.

The convention then proceeded to consider the second topic for discussion, "Is it Desirable to have Water Pipe Cast with the Bell End Down?" The discussion was opened by Mr. Brackett, and it was participated in by the President, Mr. Richards, Mr. Rogers, Mr. Washington, Mr. Nevons, Mr. Garrett, Mr. Billings and Mr. Walker. At the close of the discussion the convention adjourned until evening.

EVENING SESSION.

At the evening session Mr. Frank L. Fuller of Boston read a paper entitled "Description of Water Works at Franklin, N. H." He was followed by Mr. John R. Freeman, of Boston, with a paper on "The Arrangement of Hydrants and Water Pipes for the Protection of a City Against Fire." Mr. Brackett of Boston presented some facts in regard to the distribution system in some of the larger cities of the country.

An invitation was received from the Deane Steam Pump Co. for the members to visit their works in the morning The convention then adjourned to Thursday at 9 a. m.

MORNING SESSION.

Thursday, June 9th, 1892.

At the opening of the morning session the President called upon Mr. George A. Stacy, of Marlboro, who read a paper in which he gave an account of an experiment with a device for forcing hydrants off the ends of pipes. Mr. Dyer, of Portland, related a similar experience, and Mr. Fuller, the President, and Mr. Hyde took part in the discussion.

The next paper was by R. A. Robertson, Jr., of Providence. It gave the history and description of the Venturi Water Meter. It was discussed by Mr. Richards, Mr. Stearns, Mr. Fuller and Mr. Noyes.

The convention then proceeded with the regular order of business for the morning session.

OFFICERS 1892-'93.

The committee to nominate officers for the ensuing year submitted the following report ;

President—George F. Chace, Taunton, Mass.

Vice-Presidents—George E. Batchelder, Worcester, Mass.; Willis E. McAllister, Calais, Me.; F. P. Webster, Lakeport, N. H,; John L. Congdon, East Greenwich, R. I.; J. A. Butler, Portland, Conn.; F. H. Crandall, Burlington, Vt.

Secretary—R. C. P. Coggeshall, New Bedford, Mass.

Treasurer – Hiram Nevons, Cambridgeport, Mass.

Senior Editor—Dexter Brackett, Boston, Mass.

Junior Editor—Walter H. Richards, New London, Conn.

Executive Committee—Frank E. Hall, Quincy, Mass.; Joseph G. Tenney, Leominister, Mass.; George A. Stacy, Marlboro, Mass.

Finance Committee—F. A. Andrews, Nashua, N. H.; A. R. Hathaway, Springfield, Mass.; J. L. Harrington, Cambridge, Mass.

On motion of Mr. Ringrose the report of the committee was accepted and on motion of Mr. Noyes the Secretary was instructed to cast the ballot of the Association for the nominees, which he did, and they were declared elected.

The President. I am confident I express the sentiment of every member of this Association when I say you have made an admirable selection in choosing Mr. George F. Chace, Superintendent of the Taunton Water Works, to preside over your deliberations for the ensuing year.

THE FALL MEETING.

Mr. Beals, Superintendent, Middleboro, Mass , on behalf of the Water Board, extended a cordial invitation to the members of the Association to hold their September meeting in Middleboro. He also presented a communication from the Commercial Club of that town, joining in the invitation. And also in behalf of his associates on the Board of Selectmen, Mr. Beals still further extended the offer of hospitalities

On motion of Mr Noyes it was voted to accept the invitation, and the Secretary was instructed to convey the thanks of the Association to the Water Board, the Commercial Club and the Selectmen.

PLACE FOR HOLDING THE ANNUAL CONVENTION.

The President. The place to hold our next annual convention is the next business for consideration, and I would like to hear an expression from the members as to where we shall go. I will call on our Senior Editor, Mr. Brackett, for his opinion.

Mr. Brackett. As I am asked for my opinion on the subject I may perhaps take the liberty to digress a little, and to give my ideas upon the general question of the annual meeting. I think the time has come when

it would be well to make, as you suggested in your opening address, Mr. President, some change in the time of holding the annual meeting. It seems to me it would be much better, considering how all of our Active members are engaged at this season of the year, to hold the meeting during the winter, or in March. We might perhaps have one meeting earlier in the season than has been our custom, say in November, similar to those that we are in the habit of having during the winter. That would give us then five meetings during the year, and if we wished to have a fall meeting or an excursion that could be arranged at the pleasure of the Association each year, without having any stated time for it. As this change would require an amendment of the Constitution, I would move that a committee of three be appointed by the President to consider and report at the December meeting any changes in the Constitution which they may deem advisable.

The motion was adopted, and the President subsequently appointed as the committee Messrs. Brackett, Coggeshall and Richards.

On motion of Mr. Brackett it was further voted that the Executive Committee decide the place of the next annual convention.

NEW MEMBERS ELECTED.

The Secretary read the following applications for Resident Active Membership, which had been properly endorsed and approved.

B. R. Felton, City Engineer, Marlboro, Mass.

Allen Hazen, Chemist State Experimental Station, Lawrence, Mass.

Charles L. Knapp, Clerk of Water Board, Lowell, Mass.

Thomas W. Mann, ivil Engineer, Holyoke, Mass.

On motion of Mr. Richards the convention directed the Secretary to cast the ballot of the Association in favor of the above named gentlemen, which he did, and they were declared elected.

John L. Harrington, of Cambridge, read a paper entitled "A Canal Siphon in Cambridge."

Professor Sedgwick read a paper by Professor Thomas M. Drown of the Massachusetts Institute of Technology on "The Effect of Aeration of Water and Sewage." He was followed by Mr. Stearns, and after remarks by Mr. Mann the convention adjourned until evening.

EVENING SESSION.

At the evening session William L. Sedgwick, Professor of Biology, Massachusetts Institute of Technology, and Chief Biologist to the State Board of Health of Massachusetts, read a paper, illustrated by the stereopticon, entitled, "The Purification of Drinking Water by Sand Filtration ; Its Theory, Practice and Results ; with Special Reference to American Needs and European Experience." Mr. Stearns, Mr. Noyes, Mr. Hazen and the President took part in the diicussion which followed the reading of the paper.

W. F. Cleveland, Superintendent of Brockton, Mass., and E. H. Reynolds, Commissioner of Brockton, were elected to Active membership in the Association.

Mr. Walker. I would like to make a motion before the convention adjourns that the thanks of the Association be tendered to our retiring President, Mr. Holden, of New Hampshire, now, you know, (laughter) for the able manner in which he has presided over our deliberations during the past year. We have had good presidents right along, and I don't think you made any mistake when you took one from New Hampshire.

The motion was put by the Secretary and adopted with applause.

Mr. Holden. Gentlemen, you are all aware that as a speaker I have never been considered much of a success, and I can only say now that it has always been a work of pleasure for me to do what I could to advance the interests of this Association. (Applause.) I heartily thank you for the assistance you have given me during the past year. I will now surrender my position to my successor, Mr. Chace. (Applause.)

President Chace. Members of the Association: I thank you for the honor you have conferred upon me, and I assure you I feel it is an honor to preside over such a body of men. I may not be young in years, but I am young in the Water Works business. Something like four years ago I knew no more about managing a Water Works than a child. I was invited by the Water Commissioners of Taunton to succeed Mr. Billings. I felt very much as Cæsar must have felt when he crossed the Rubicon and didn't know what the result might be. But I never did have much respect for a man who didn't have courage, and I resolved to plunge in and take the chances. Every man, you know, feels very comfortable, when he has just won a fight, especially if no blood has been shed. I found the Taunton Water Works in a good condition. They had been well managed in a mechanical way, but like many other cities to which allusion has been made, it possessed a supply not altogether satisfactory in some respects. The reasons for the condition in which it was, have been partly suggested in the paper you have listened to tonight. I considered it my duty as the superintendent to find out what there was in the supply of Taunton which was not right and why it was not right. I knew very little about such things when I took charge of the works, but you honored me with membership in his society, and I learned a good deal from the members of this Association. And if I have had any success in the management of our works it is due very largely to you. And I assure you that if this society succeeds in the future it will be due in the coming year not to the President, but to you, the members of the Association. I shall endeavor to do my duty, and I know you will do yours. But you do not wish to hear a long speech at this time, and I will defer any further remarks until some other occasion. (Applause.)

On motion of Mr Fuller the thanks of the Association were tendered the Parsons Paper company, the Merrick Thread company and the Deane Steam Pump company for attentions shown.

On motion of Mr. Mann a vote of thanks was tendered Professor Sedgwick for his very able paper.

On motion of Mr. Richards the convention adjourned.

The social features of the convention were more extensive than usual and were thoroughly enjoyed and appreciated. Through the courtesy of the Deane Steam Pump company visits were made by members and ladies to the Parsons Paper mills, the Merrick Thread mill and the works of the Deane Steam Pump company. The members were much interested in the systematic arrangement of the latter works, the details of which were explained by the courteous attaches of the company. Under the escort of Mr. L. E. Bellows and Mrs. Bellows the members and ladies listened to an organ recital in the Second Congregational church by William Churchill Hammond. The works of the Holyoke Machine company were also visited.

On Friday morning at the invitation of the Board of Water Commissioners a visit was made to the reservoirs supplying the city with water. The entertainment concluded on Friday afternoon with a trip to Mount Holyoke on the invitation of the Deane Steam Pump company, and under the escort of Mr. Charles P. Deane, Mr. L. E. Bellows and Mrs. Bellows, and Mr. C. L. Newcomb and Mrs. Newcomb. About seventy-five members, ladies and guests, were taken by rail to Mt. Tom station where they were ferried across the Connecticut river and from there conveyance was furnished by barges to the foot of Mt. Holyoke. The ascent of 600 feet was made by most of the party on the cable road, a few preferring to climb the 522 steps to the summit. The party after enjoying the magnificent view from the summit were served with lunch at the Prospect House.

During the return trip while waiting for the train at Mt. Tom station the Association was called to order by President Chace and on motion of Mr. Decker a vote of thanks was tendered to the Deane Steam Pump company, Mr. Charles P. Deane, Mr. and Mrs. L. E. Bellows, Mr. and Mrs. C. L. Newcomb and the Water Board and Superintendent of Water Works of the city of Holyoke. The party returned to Holyoke in time for the late afternoon trains enthusiastically expressing their gratitude for the liberality of their entertainers.

LIST OF EXHIBITS BY ASSOCIATE MEMBERS AT THE CONVENTION.

National Meter Co., New York city, Water Meters.
Hersey Manufacturing Co., Boston, Mass., Water Meters.
Union Water Meter Co., Worcester, Mass., Water Meters.
Thomson Meter Co., Brooklyn, N. Y., Water Meters.
Anthony P. Smith, Newark, N. J., Machine for Tapping Mains.
Henry R. Worthington, New York, Water Meters.
R. D. Wood, Philadelphia, Pa., Gates and Hydrants.
Michigan Brass and Iron Works, Detroit, Mich., Gates and Hydrants.

Chapman Valve Mfg. Co., Indian Orchard, Mass., Gates, Hydrants and Valves.

Taunton Locomotive Works, Taunton, Mass., Service Boxes and Lead Furnace.

Crosby Steam Gage and Valve Co., Gages, Valves and Gage Testing Machine.

Walworth Mfg. Co., Boston, Mass., Hall Tapping Machine, Valves, Cocks and Tools.

Chicago Meter Register Co., Chicago, Meter Register.

Ross Valve Co., Troy, N. Y., Balance Valves, Gates and Water Engines.

King and Goddard, Boston, Mass., Service and Valve Boxes.

The Fairbanks Co., Boston, Mass., Renewable Asbestos Seat Gates, Valves and Swing Checks.

Holyoke Hydrant and Iron Works, Holyoke, Mass., Hydrants.

Perrin, Seamans & Co., Boston, Mass., Construction Tools.

Moore Filter Co., Holyoke, Mass., Filters.

Rudolph Brandt, New York city, Selden Packing.

Hydraulic Construction Co., New York city, Driven and Tube Well Points.

Deane Steam Pump Co., Holyoke, Mass., Drawings of Steam Pumps.

ATTENDANCE AT CONVENTION HELD IN HOLYOKE JUNE 8, 9 AND 10, 1892.

ACTIVE MEMBERS.

E. L. Abbott, of New York city.
H. W. Ayres, of Hartford, Conn.
C. H. Baldwin, of Boston, Mass.
R. Baldwin, of Terryville, Conn.
J. E. Beals, of Middleboro, Mass.
N. B. Bickford, of Boston, Mass.
W. R. Billings, of Taunton, Mass.
Dexter Brackett, of Boston, Mass.
G. F. Chace, of Taunton, Mass.
C. E. Chandler, of Norwich, Conn.
Ezra Clark, of Hartford, Conn.
W. F. Cleveland, of Brockton, Mass.
W. F. Codd, of Nantucket, Mass.
R. C. P. Coggeshall, of New Bedford, Mass
B. I. Cook, of Woonsocket, R. I.
F. H. Crandall, of Burlington, Vt.
G. K. Crandall, of New London, Conn.
J. H. Decker, of New York city.
A. N. Dennan, of Des Moines, Iowa.
C. R. Dyer, of Portland, Me.
H. L. Eaton, of Somerville, Mass.
J. R. Freeman, of Boston, Mass.
F. L. Fuller, of Boston, Mass.
E. P. Gardner, of Norwich, Conn.
A. S. Glover, of Boston, Mass.
S. E. Granniss, of New Haven, Conn.
F. E. Hall, of Quincy, Mass.
J. C. Hammond, Jr., of Rockville, Conn.
John L. Harrington, of Cambridge, Mass.
D. A. Harris, of New Britain, Conn.
John C. Haskell, of Lynn, Mass.
M. Hastings, of Cambridge, Mass.
A. R. Hathaway, of Springfield, Mass.
H. G. Holden, of Nashua, N. H.
A. W. Hunking, of Dayton, Ohio.
H. N. Hyde, of Newtonville, Mass.
D. B. Kempton, of New Bedford, Mass.

C. L. Knapp, of Lowell. Mass.
J. A. Lockwood, of Yonkers, N. Y.
T. W. Mann, of Holyoke, Mass.
T. H. McKenzie, of Southington, Conn.
W. E. McNally, of Marlboro, Mass.
J. H. Morse, of Natick, Mass.
Hiram Nevons, of Cambridge, Mass.
E. C. Nichols, of Reading, Mass.
A. F. Noyes, of Newton, Mass.
E. H. Phipps, of New Haven, Conn.
W. E. Rawson, of Uxbridge, Mass.
E. H. Reynolds, of Brockton, Mass.
W. H. Richards, of New London, Conn.
G. J. Ries, of Weymouth, Mass.
J. W. Ringrose, of New Britain, Conn.
H. W. Rogers, of Haverhill, Mass.
Daniel Russell, of Everett, Mass.
A. H. Salisbury, of Lawrence, Mass.
W. T. Sedgwick, of Boston, Mass.
J. D. Shippee, of Holliston, Mass.
Geo. A. Stacy, of Marlboro, Mass.
F. P. Stearns, of Boston, Mass.
Wm. P. Swett, of Terryville, Conn.
R. J. Thomas, of Lowell, Mass.
Chas. K. Walker, of Manchester, N.H.
J. C. Whitney, of Newton, Mass.
E. T. Wiswall, of Newton, Mass.
L. C. Wright, of Northampton, Mass.

Total, 65.

ASSOCIATE MEMBERS.

L. B. Adams, representing Peet Valve Co., Boston, Mass.
C. L. Allen, representing Holyoke Hydrant and Iron Works, Holyoke, Mass.
A. H. Austin, representing King & Goddard, Boston, Mass.
J. E. Batchelder, representing Deane Steam Pump Co., Holyoke, Mass.
L. E. Bellows, representing Deane Steam Pump Co., Holyoke, Mass.
J. M. Betton, representing Henry R. Worthington, New York city.
H. L. Bond, representing Perrin Seamans & Co, Boston, Mass.
Randolph Brandt, representing Seldens Patent Packing, New York city.
J. F. Browning, representing the Fairbanks Co., Boston, Mass.
J. H. Carpenter, representing the Fairbanks Co., Boston, Mass.
G. H. Carr, representing Union Meter Co., Worcester, Mass.
Chas. P. Deane, representing Deane Steam Pump Co., Holyoke, Mass.
F. W. DeBerard, representing Meter Register Co., Chicago, Ill.
C. H. Eberle, representing Crosby Steam Gage and Valve Co., Boston, Mass.
J. H. Eustis, representing Walworth Mfg. Co., Boston, Mass.
George B. Ferguson, representing H. R. Worthington, New York city.
H. C. Folger, representing Thomson Meter Co., Brooklyn, N. Y.
Jesse Garrett, representing R. D. Wood & Co., Philadelphia. Pa.
Jason Giles, representing Chapman Valve Mfg. Co., Indian Orchard, Mass.
J. J. Hart, representing King & Goddard, Boston, Mass.
F. H. Hayes, representing Deane Steam Pump Co., Boston, Mass.
F L. Howland, representing the George Woodman Co., Boston, Mass.
G. S. Hoyt, representing George K. Paul & Co., Boston, Mass.
Wm. P. Johnson, representing Mason Regulator Co., Boston, Mass.
John C. Kelley, representing National Meter Co., New York city.
F. S. King, representing National Meter Co., New York city.
Frank Lambert, representing Thomson Meter Co., New York city.
W. B. Meldon, representing Thomson Meter Co., New York city.
E. B. Miles, representing Deane Steam Pump Co., Holyoke, Mass.

G. H. Moore, representing Moore Filter Co., Norwich, Conn.
Chas. L. Newcomb, Deane Steam Pump Co., Holyoke, Mass.
J. P. K. Otis, representing Union Meter Co., Worcester, Mass.
A. M. Pierce, representing Deane Steam Pump Co., Boston, Mass.
B. Frank Polsey, representing Walworth Mfg. Co., Boston, Mass.
R. A. Robertson, Jr., Treasurer Builders Iron Foundry, Providence, R. I.
E. L. Ross, representing Chapman Valve Mfg. Co., Indian Orchard, Mass.
George Ross, representing Ross Valve company, Troy, N. Y.
A. P. Smith, Connecting Machines, Newark, N. J.
J. E. Spofford, representing Hersey Meter Co., Boston, Mass.
F. E. Stevens, Secretary Peet Valve Co., Boston, Mass.
L. W. Summer, of Summer & Goodwin, Boston, Mass.
J. A. Tilden, representing Hersey Mfg. Co., Boston, Mass.
W. H. Van Wrinkle, representing A. P. Smith, Newark, N. J.
W. d'H. Washington, representing Hydraulic Construction Co., New York city.
William Wolfendale, Plumbers Supplies, Fall River, Mass.

Total, 45.

HONORARY MEMBERS.

M. N. Baker, of "Engineering News," New York city.
F. W. Sheppard, of "Fire and Water," New York city.
C. J. Underwood, Jr., of "Engineering Record," Boston, Mass.

Total, 3.

GUESTS.

J. P. Bacon, Cambridge, Mass.
Mrs. Chas. H. Baldwin, Boston, Mass.
Mrs. J. E. Beals, Middleboro, Mass.
C. H. Beaton, New Britain, Conn.
Mrs. L. E. Bellows, Holyoke, Mass.
A. A. Blossom, Salem, Mass.
Mrs. Dexter Brackett, Boston, Mass.
Mrs. R. Brandt, New York city.
Mrs. R. C. P. Coggeshall, New Bedford, Mass.
J. J. Curran, Holyoke, Mass.
Mrs. A. N. Dennan, Des Moines, Ia.
Philip Eley, Bayonne, N. J.
Mrs. A. S. Glover, West Newton, Mass.
Mrs. Jason Giles, Indian Orchard, Mass.
C. L. Goodhue, Springfield, Mass.
J. H. Hardy, Holyoke, Mass.
Frank A. Holden, Springfield, Mass.
C. F. Holyoke, Marlborough, Mass.
Mrs. John C. Kelley, Brooklyn, N. Y.
Miss C. A. Kelley, Brooklyn, N. Y.
Miss S. E. Kelley, Brooklyn, N. Y.
Mrs. D. B. Kempton, New Bedford, Mass.
Miss M. L. Kirtband, Holyoke, Mass.
Mrs. T. H. McKenzie, Southington, Conn.
Miss Emma McKenzie, Southington, Conn.
Miss Fannie McKenzie, Southington, Conn.
Mrs. C. L. Newcomb, Holyoke, Mass.
Miss C. Nichols, New York city.
Mrs. W. H. Richards, New London, Conn.
Mrs. E. L. Ross, Indian Orchard, Mass.
S. H. Taylor, New Bedford, Mass.
Mrs. J. H. Tilden, Boston, Mass.

Total, 32.

Total attendance, 145.

TOPICAL DISCUSSION.

IS IT DESIRABLE TO HAVE WATER PIPE CAST WITH THE BELL END DOWN?

Mr. Brackett. I should like to know with regard to the experience of the members as to whether they have their pipe cast with the bell end down or up, and as to whether they have any difficulty from the leaking of the pipe at the bell, or whether they ever break the bells in driving joints. My experience has been that pipes cast with the bell down have a much more solid and clean head, are less liable to shrinkage cracks in the neck, and have sockets of more uniform size and depth than when cast with the bell at the top.

The President. Four years ago I had a lot of pipe come which I judged must have been cast with the bell end up, for we had several leaks at the bells and we have never bought any of that company since. The pipe we have bought since I suppose was cast with the bell end down, because occasionally we will find a spigot end where there is an inch or two of rather porous iron, and it is very easy to cut that off.

Mr. Richards. I had quite a long line of pipe cast recently bell end down, and after observing it carefully I came to the conclusion that hereafter I would have it cast bell end up. (Laughter.)

The President. I am glad there are two sides to this question.

Mr. Richards. It seems to me the difference is just here. If you use a shallow bell it is better to have the imperfection there, if there is any, and it is less likely to be in the bell than it is in the spigot end. It seems to me it is better to have it in the bell, because, if there is spongy, porous iron in the spigot it is liable to check and run along the pipe and make a leak, or if there is a bad place in the spigot, you have to cut it off; whereas, if it is in the bell the lead would prevent it from leaking, and it would do no harm. The bell ought to be heavy enough so it will bear caulking, even if it is a little imperfect. It seems to me that, with a shallow bell, particularly, I had rather have the pipe cast bell end up. With a deep bell it may be that the lead would cover most of the imperfections. I must say I do not agree with the majority of engineers in this, for I believe they prefer to have it cast bell end down.

Mr. Nevons. We are laying about eight miles of pipe this year, all of it cast with the bell end up. When the parties who bid on it told me that that was their method of casting and wanted to know if I had any objections, I wrote to them I would go out to their works before we decided. I went out, and I looked the matter all over, I saw their pipes and examined very carefully the bell end, and I must say I decided I had rather have the pipes cast with the bells up. Now, if a leak occurs at all you will generally find it on the spigot end of the pipe, and I had rather have the poor iron, if there is any, as Mr. Richards said, in the bell than to have it in the spigot. However, I don't think you get much poor iron in the bell any way. They won't let the dross go in there, and in all the pipe we have had I haven't seen any but what looked solid and firm. The bell is a little rougher, and I don't know but that is all the better, for it holds the lead. Of course I wouldn't specify to have

them made rough, but I don't think it is any objection, for it is going in the ground. But I do like to have a good solid spigot, a smooth, fair surface around it, and I had rather have the perfect casting on the spigot than to have it in the bell and not have it in the spigot. As I said before, I don't believe that you get much poor iron in the bell. If the iron is properly mixed when poured you get a clear mixture all the way up. It seems to me the only objection that any one can raise against casting the pipe with the bell up is that it makes it a little rough, but I myself don't consider that an objection at all.

The President. We would like to hear from Mr. Rogers.

Mr. Rogers. My preference would be from the experience I have had, to have the bells cast on the bottom. My experience has been that I have more trouble with blow-holes than with dross or bad material, and those seem to occur more particularly on top. Out of a lot of 3,000 pieces of 30-inch pipe that we used two years ago, which were cast bells down, we had some ninety pieces broken on the spigot end, showing that there was weakness there ; and on cutting the pipe we found it blowy and imperfect, whereas we did not have an imperfect socket in the whole lot. If I should make any change from the ordinary way of casting pipe with the bell down, it would be to cast the pipe six or eight inches longer than I wanted and cut it off above the spigot end, so as to get rid of the porous pipe which comes on top and shows imperfections. I myself would sooner have the socket sound and firm for my spigot end than to have the socket poor, because it makes a more difficult leak to repair where the socket is cracked or broken than where the spigot end is. My experience may not be that of others, and may not be worth speaking of perhaps at all, but such as it has been it is in favor of the pipe being cast socket downward.

Mr. Nevons. I would like to say that the only case of a blow-hole in a bell I ever had was in a pipe which was cast bell down. (Laughter.)

The President. Are you sure it was?

Mr. Nevons. Yes, sir ; I am sure of that, for I made special investigation with regard to it.

The President. As to this pipe to which I referred that we had four years ago, of course I am not certain whether it was cast bell down or bell up, but my impression is it must have been cast with the bell up. The pipe was well coated and looked all right, but after it was laid we had several leaks from little blow-holes that showed out through the top of the bell. The bells were four inches deep. These holes must have reached way through into the pipe, and came out through the end of the bell. On examining several of those I had to take up I found they were full of little holes apparently three or four inches in length.

The President. We will be glad to hear from any practical moulder.

Mr. Washington. I can't say that I am a practical moulder exactly, but when I was a boy I had a mechanical turn, and I got a slight idea of how iron is moulded and how iron acts when being poured. (Mr. Washington described the method of making castings but stated that he had had no experience with pipe casting.) If you can get a perfect spigot at the lower end, I should favor having the bell up from a water works standpoint from the fact I don't think you will get a great deal of dross.

Mr. Garrett. Mr. Washington has certainly given a very practical exposition of the general method of casting. I doubt very much, though, whether in pipe casting the effect very often happens, that Mr. Washington refers to, in regard to the chilling of the outside of the pipe when it is being cast. The mould and the core are very recently removed from the ovens, and they are very dry. When the molten iron is poured the straw of the core immediately begins to burn, and I think that in itself would to a certain extent prevent the chilling of the inside of the pipe, even if it were not almost an impossibility for it to chill any how to any detriment. Pipes are all cast in dry sand, and both the core and the mould are thoroughly dried and heated in the oven before the pipe is cast.

Now, with regard to casting head up or head down, I think there is about as much diversity of opinion in this Association and among engineers generally as there are patterns in a foundry. (Laughter.) I don't believe that Mr. Nevons or Mr. Holden or Mr. Brackett can tell when the pipes come to them, whether they are cast head up or head down. (Laughter.) Years ago there was no such thing as casting head down, and now if there is no specification and no inspection, you are just as likely to have your heads cast up as you are to have them cast down, and I don't believe you will be able to tell when the pipes come to your works whether they have been cast one way or the other. I think, however, there is a good deal to be said on both sides, and I think Mr. Nevon's idea is a very good one, that if you are going to get bad iron you might just as well have it in one end as in the other. But manufacturers don't intend to put bad iron into their pipe, and they are very careful that the dross shall not go into their pipes. But suppose that in the last pipe poured with the last of the iron in the ladel, there is some possibility of dross getting into the pipe ; now, there is a question if it is not better for that to be distributed over the greater section of the bell than over the smaller section of the spigot, or whether there isn't much less danger of the pipe being weakened in any way by the distribution through the greater section. It is a question that is not settled.

Mr. Nevons. The gentleman (Mr. Garrett) has suggested that we wouldn't any of us know whether our pipe was cast spigot end down or bell end down, If he doesn't put it into a lathe I shall have to take exception to what he says about it, for I think almost any water works man can tell whether a pipe is cast bell up or bell down.

Mr. Garrett. We do it sometimes. (Laughter.) I admit that there is a method there by which you could tell, by the feather edge. But what I meant was that with regard to the quality and texture of the bell or spigot I didn't believe one of you would be able to tell.

The President. I should like to hear an opinion from Mr. Billings. (Applause.)

Mr. Billings. I have been very much interested in what has been said. Of course every foundryman knows, every one who has had any acquaintance with a foundry knows, that on general principles if you want to get good, sound, smooth castings you put the part you wish to get the best in the lower part of the flask, and you get the best iron in the bottom and, on

general principles, the poor iron comes to the top, if there is any poor iron or any dirt or dross of any kind. All I can say about the matter is that I think, as Mr. Garrett has already intimated that this is a question for foundrymen to discuss among themselves, rather than for water works men or engineers. It seems to me that what the engineers have a perfect right to do is to set up a standard which they wish the foundrymen to reach, and then accept the work that on the whole reaches the standard with the best results. But when an engineer tells a foundryman he shall cast his pipe this way, that way or the other, it seems to me, with all due respect to my friends, he is going out of his province, and that the foundryman should be left to use his own judgment, provided he furnishes good pipe and sound pipe and pipe that is what it ought to be. Because so far as I know anything about it it is not a question of whether the bell be up or the bell be down. It is a question of the proper materials and pouring and venting and of all the details of practical foundry work which engineers are not supposed to be especially familiar with. And I would suggest that we amend our specifications so that we shall say exactly what kind of pipe we want, and then let the foundrymen manufacture it in the way that seems best to them to produce that result. (Applause)

Mr. Richards. I think Mr. Billings is wrong in his proposition, and that the engineers have a perfect right to specify which end shall be cast down. If they want the honeycombed end the bell end they have a right to say so and have it made so, and if they want it in the spigot end they have a right to say that. If the pipe manufacturers do not care to bid on the specification they are not obliged to.

Mr. Brackett. In Boston we require the pipes to be cast with the bell end down because we prefer to have that poor end of the pipe the spigot end. That is the only reason for specifying that the bell end of the pipe should be cast down. Whether it is a question of the poor iron, or of the pipe being honeycombed by the air which collects in it, the fact is that the ends of the pipes are honeycombed. That is a fact which I know from practical experience. And I have no doubt but that if the pipe were cast the other end up the honeycombing would be in the bell end ; and in Boston, at least, we prefer to have it in the spigot end.

Mr. Washington. I wish to differ from the gentleman behind me (Mr. Billings.) I think engineers have a right to demand of the foundrymen what they want, but at the same time they ought to know why they demand it. They ought to have sense enough to determine the question from the different results to be obtained by casting bells down or bells up. And so I think it is a very desirable thing to settle this matter one way or the other as to which is the best method, and if a man is going to demand it bell down he ought to be able to give his reasons why it is better bell down.

DETECTING A WASTE OF WATER

BY

Byron I. Cook, Woonsocket, R. I.

Detecting a waste of water is a common occurance with the water superintendent, and when located he is oftentimes surprised at the willful neglect and carelessness of the water consumer.

The incident that I am about to relate occured in the month of January 1891, there being at that time about two feet of frost in the ground. It may be well to describe the works at Woonsocket, as in so doing it will illustrate what I have to say.

The Pumping Station is situated about three miles southeast from the city, and midway between that and the city are located the stand pipes, the stand pipes are connected with pumping station by one of Geo. E. Winslow's recording gauges graduated to show a variation of three inches equal to 7,343 gallons, the holding capacity being small the daily consumption is very accurately obtained, the supply main from stand pipes is fourteen inches, and runs to the center of city, the arrangement of gates is such that the city can be divided into four sections each being independent of the other.

The city has not any system of sewerage, the Blackstone river passes through it nearly in the shape of the letter S. and every one that can has a sewer of his own connected with the river, and constructed according to his own idea, the variety is great and consists of wooden boxes, blind drains, stone culverts, cracked water pipe, sewer pipe, etc. It will be readily seen that a leak in the water mains could pass off through one of these drains, and into the river and not appear on the surface.

On the morning of Saturday, January 24th, when the engineer telephoned the consumption for the day and night previous, as is the custom, I noticed that the consumption for the night had increased 60,000 gallons. I called his attention to the fact, and told him to report to me at noon if the loss continued during the morning ; at noon he reported the consumption was still large.

Woonsocket had the misfortune, if I may call it that, to have its works built by a company, and, as a consequence, there were some things allowed by the company that would have been different if built by the city, the Water Company allowed the Manufacturing Companies to connect their pipe system with the Water Works system, most of this piping was of light weight and poorly laid. During the past winter I had a chance to examine some of this old pipe, a six-inch main I found less than a quarter-inch thick ; this same pipe has been for the past six years under 110 pounds pressure. As I have wandered from my text it has been only to show where I might expect to find a leak in case of a loss of water. Saturday afternoon was spent in visiting the different manufacturing establishments testing their piping and

everything was found all right. Saturday night the loss was about the same as Friday. Sunday the force main was tested and all culverts and waterways visited, but nothing was found. I came to the conclusion that the water was running into the river through some sewer or drain. Sunday night section one was shut off. My method of testing a section is as follows: I shut the water off at about 10:30 P. M., stationing a man at a gate to let on the water in case of fire, and at 4:30 A. M. it is turned on again; if, on consulting my gauge, I find that I have lost water, I have located the leak in that section, then that section is sub-divided until the trouble is located. Monday morning I found the trouble was not in section one. Monday night section two was tried and the leak not located. Tuesday night section three was shut off, a portion of this section for about a thousand feet runs parallel to a trench that supplies a number of mills with water. Wednesday morning the gauge showed the usual consumption and I supposed I had located the leak, concluding that the water was making into the trench. Wednesday night after the mills had shut down I had the trench drawn, leaving about two feet of water; procuring a boat I made an examination the entire length of the trench, but did not find anything that indicated a leak in the water mains. After examining the trench I shut off the same section I did the night previous, when, to my surprise Thursday morning, I found I had lost water. Thursday and Friday nights two sections were shut off, but the trouble was not located. Saturday night I decided to try the mill supplies again; the first that I tried was a new concern, and had only been in operation about three months. I shut the gate that controls the supply, and upon opening it I heard water running through. I knew that something was wrong. I telephoned the agent and informed him that there was a leak at his mill. He said he guessed everything was all right; that I must be mistaken. I told him that I would meet him at the mill in half an hour and prove to him that he was wrong.

We went through the mill, but could not find anything wrong with the fire supply. As I passed the meter I noticed that it was running very hard; I called his attention to the fact, and asked what he was using water for in so large a quantity. He said he didn't know, but would send for his master mechanic. He arrived, and was questioned why the meter should be running. He said he was filling the tank in the tower. I asked him how large the tank was, and he informed me that it was 10x12, 6 feet deep. How long does it take to fill a tank 10x12, 6 feet deep with an inch supply, 115 lbs. pressure, and where does the water go when the tank is full? Out of the overflow into the river,

To make a long story short the facts of the case are this, on the Friday before the loss of water was reported from the pumping station, the pump that supplies the tank broke down and the city water was turned on, it run constantly until Tuesday night when it was shut off to do some repairs and Wednesday morning turned on again within half an hour of the time I let water into the section that I was testing which accounts why I did not lose water that night, and run until I discovered it Saturday night. The amount that passed through the meter for the week was 2,003,603 gallons, and at the

schedule rates amounted to $200.36 and was paid for by the company, but not without some grumbling.

The reason that I did not discover that the meter was running when I first tested the supply was because I shut that off in order to test the fire supply and as all the piping for the tank is in plain sight I could not see how there could be a leak in that and not be discovered, or that anyone could be so careless as to leave it running.

AN EXPERIMENT AND A FAILURE

BY

George A. Stacy, Supt., Marlboro, Mass.

About four years ago I had a number of hydrants to move back occasioned by the widening of a street. As this, of course, required that the water be drawn off from the main while the work was going on, I wished to finish the job as soon as possible. I thought if I had some device for forcing the hydrants off the end of the pipes, that could be easily applied and quickly worked, and having the extension pieces ready and lead hot, I could make a quick job of it.

I looked over the files of the Association Journal to obtain what information I could from the experience of others, but found very little on this particular subject. One man from Connecticut, I believe, said he removed hydrants by taking hold of the top and with two men working them back and forth, pulled them right off. I have tried that but did not have very good success. I then made up my mind to make the attempt to force them off, and made a machine as follows :

Two pairs of clamps made of 3x$\frac{7}{8}$ wrought iron drawn together by $\frac{7}{8}$ bolts and lined with leather ; these clamped on to the pipe made one abutment, and the face of the bell of the hydrant the other. I then made a screw jack with two 1$\frac{1}{2}$ steel screws, eight threads to the inch, working in cast-iron blocks ; these blocks bolted to two wrought-iron yokes 3x$\frac{7}{8}$, the whole making a ring whose internal diameter was $\frac{3}{4}$ larger than the outside diameter of the 6 in. pipe. Brackets on the front side of the cast-iron blocks held the ring centered and when the jack was pressed against the face of the hydrant the lead joint was clear all around. A cast-iron button was made to be placed between the heads of the 1$\frac{1}{2}$ inch screws and the clamps on the pipe.

After making this machine I tried it in the shop by putting together a bell and spigot piece of pipe and made the joint in the usual manner ; then we put on the jack and I told my man to jack it out, and awaited the result. After getting a good strain on the jack the pipe started and responded to every turn of the wrench. Visions of success flashed across my mind and I was about to cry "Eureka" when there was a hitch in the proceedings. My

man could not start the screw. We had the pipe drawn a little over an inch; both of us got hold of the wrench and we got about one-half inch more, then the clamps slipped; we screwed them up and tried again, but of no use, we could not start the pipe.

I carried the experiment no further for I was satisfied that the machine was a failure for the purpose for which it was designed, for the reason that while the machine would easily force a hydrant off a straight plain piece of pipe, yet if a hydrant was set with a pipe which had a bead on the end (and we have set all our hydrants that way when possible) when the bead struck the lead in the joints the machine came to a stand-still, but perhaps with a longer lever on the wrench and more clamps on the pipe I could force the hydrant off; yet the labor and expense would be more and it would take more time than to cut it off with hammer and chisel. So we finished the job in the old way.

It is more pleasant to record a success than a failure, yet no one need be ashamed of a good honest attempt, even it ends in failure, for I think that often-times the knowledge and experience gained from some of our failures are more valuable and lasting than that gained from some of our successes.

The President. Gentlemen, this failure of Mr. Stacy's is before you for consideration. Perhaps some of you can suggest some device which would answer.

Mr Fuller. I would like to ask Mr. Stacy why he couldn't have forced it off, the opposite end from the end which went into the hydrant.

Mr. Stacy. Mr. President, the idea in this case was to avoid excavation in moving the hydrants back. If the main is on the other side of the street you don't want to go out to the main, dig up the street and shove the whole thing over. It would take more time than it would to cut it off with hammer and chisel.

The President. It seems to me it would be very difficult to force the pipe off the hydrant where the bead end goes into the hydrant, as they have some half an inch of bead all around to pull out, with the pressure of the lead behind it. It would be cheaper to cut the pipe in two and put in a splice.

Mr. Stacy. That is the way it was done. I will say I didn't want to go on to the street with this thing, as we have a pretty large sidewalk committee there which would want to know what this was for, so I tried it in secret session, and I satisfied myself that a jack wouldn't take off most of the hydrants. If I had only known where there was a hydrant without a bead on it I would have used the jack, but I wasn't sure of that, so we used the hammer and chisel which I knew would work. And it takes a pretty good machine that will beat a hammer and chisel on a 6-inch pipe.

Mr. Dyer. I may relate a little experience we have had in Portland. We took up a line of 6-inch cast iron pipe some half mile in length to replace it by 16-inch, and we took it up in double lengths, sometimes three, at a time. And having it all on the ground we naturally looked for the most feasible way to separate the joints, and we went to work something as the gentleman has stated he did, and had clamps made very strong, and clamped them around the pipe just in front of the bell. Then we procured some jacks with about an inch and three-quarters screw, and we arranged two of those at a time, one each side of the pipe, and were able, as he has stated he was, to move the pipe some three-quarters of an inch, or, perhaps, an inch, but no further. We screwed our jacks up until we spoiled two of them, but in no case were we able to separate one joint, and we had to resort to melting them out by means of fire, as they were on the bank. And that is the only way we have ever been able to separate pipes under similar circumstances.

The President. That seems to be the general experience of most every one who has undertaken to pull pipe apart. We have always cut pipe in preference to building a fire under it. I consider it cheaper, and there is very little waste, not over five or six inches of the pipe, and I have always considered that preferable, to cut the pipe up close to the bell, and then break out what pipe there is in the bell, rather than to undertake to build a fire.

Mr. Hyde. We use what is called the Providence bell, a shallow bell, and I have pulled apart 800 feet of 12-inch pipe in a little more than half a day and put it out on the bank. It was a case where the grade was changed at a bridge going over a railroad. We cut one end and put a derrick under the end which was cut, raised it up what we could with the derrick and threw dirt under the second bell, and had a couple of men get on the end of the pipe and jump it a little, then raised up a little on the derrick, and we pulled them all out without any trouble. Of course we couldn't have done that with a 4-inch bell, but with our bells we did it very comfortably.

The President. What is the depth of your bells?

Mr. Hyde. Two and a quarter inches.

The President. I can readily see how that can be done with a shallow bell, with a bell three and a half or four inches deep it would be much more difficult.

Mr. Hyde. It is plenty deep enough.

FIRE PROTECTION.

TWO METHODS OF OBTAINING FIRE PROTECTION BY DIRECT HIGH PRESSURE FROM WATER WORKS PUMPS IN COMBINED PUMPING AND RESERVOIR OR STANDPIPE SYSTEMS.

BY

GEO. A. ELLIS, Civil Engineer, Boston, Mass.

In most of the lesser cities and in nearly all of the smaller ones and large towns having a public water supply, it is customary to depend in some measure upon direct connection of the fire hydrants with leading lines of hose, for fire streams, both for use against incipient fires and in case of wide-spread conflagrations.

This use varies from the slight requirements in the first instance, to that where the water works hydrants are relied upon for the principal protection against fire, the fire engines forming a reserve force in case of accident, needed increase of the number of streams or of extremely long lines of hose.

So thoroughly does a good water works plant assist the efforts of the firemen, that streams from such plants are desired by them as the most effective attainable; while both parties recognize the exigencies requiring the retention and use of steam fire engines.

It therefore, becomes a question, how far the principal of direct pressure from the pumps, can be advantageously applied to fire protection. This question is not entirely one of population or of pumping capacity, nor can the burning of a few tons of coal be taken as its measure, but it must be settled by the relation of pumping capacity to consumption.

If the pipe system is well designed, able to convey the volume of water required without undue loss from friction and the pipe itself able to withstand the strains and shocks arising from direct pressure, then direct pressure is desirable for fire protection, so long as the ordinary consumption, plus the waste due to the increased pressure, still leaves a safe margin, within the capacity of the pumps, for all fire streams likely to be needed, (supposing no scarcity of water to exist.)

This condition will, therefore, vary not only with different cities and plants, but also with each city and plant at varying seasons of the year and at different hours of the day.

Many cities and towns are supplied entirely by direct pressure, so that the advantages to be derived therefrom for fire protection are already theirs. It has, however, been found that in all cases where practicable, it is desirable to supplement the pumps by storage reservoirs at sufficient elevation to

supply the ordinary consumption and in some instances at elevations sufficient for fire streams.

While in the smaller cities, where suitable elevations for the construction of reservoirs do not exist, in order to avoid the expense of continuous pumping, especially during the night, recourse is had to standpipes of iron or steel to act as small reservoirs, but which owing to the topography of the surrounding country, are seldom sufficiently high to afford efficient fire streams. In order to take advantage of the pumps for direct pressure, gates are usually introduced in the main connecting with the reservoir or standpipe, by which they can be shut off and the whole power of the pumps applied through the distribution system. In some cases the reservoirs or standpipes are connected with the distribution system only by the force main via the pumping station, where by proper gates and connections, the force main can be cut out without interfering with the distribution, which thus becomes subject to direct pressure. Other means have been adopted by different engineers, to obtain this much desired result, with varying degrees of success. A description of two of these methods tried by the author, may therefore, be of interest to others studying the same problem.

The first method was suggested by the striking apparatus connected with the bell of an ordinary fire alarm, viz., motion by means of a weight suspended to a wire rope wound around a drum connected by revolving gears to a ratchet wheel, from which the pawl was released by magnetic action produced by a current of electricity.

The details of this scheme were worked out by the "Coffin Valve Manufacturing Company" of Boston, Mass., and the apparatus was attached to one of their 10-inch gates in the vertical 10-inch supply pipe to the Racine, Wisconsin, standpipe, in the spring of 1887.

The apparatus was set so that the axle of its drum was in line with the spindle of the gate, to which it was attached by a socket extension.

When the pawl was tripped, the fall of the weight was retarded by a fan, attached to the axle of the ratchet wheel, whose angle of striking the atmosphere, could be changed so as to regulate at will, the length of time required for the weight to drop and in which to close the valve ; the time required in this instance so as not to jam the valve being found to be about thirty seconds.

The pumps being run slowly at the time of tripping the valve, which is done from the pumping station, the engineer is not taken unawares, and no water hammer occurs, but watching his gauge, he carefully increases the engine speed, till the proper pressure for fire streams is attained, after which only the same watchfulness is required as in ordinary direct pressure.

The standpipe in this case is situated on a pedestal 55 feet high, and furnished with separate inlet and outlet pipes ; the former 10-inch diameter, fitted with the gate already described ; the outlet pipe 16-inch diameter with gate and check valve ; while the inlet pipe rises from the outlet pipe just on the pump side of the check valve.

The pipe, gates, weights and apparatus, are contained within annular chambers 4 feet wide and 15 feet high, within the pedestal.

Electrical connection (open circuit) is made between the standpipe and pumping station, one and one-fourth miles apart, with the usual size, galvanized iron wire, with the exception of across the Root River, where there is a submerged cable connection. At the pumping station there is a battery of the usual power required to work a fire alarm circuit of equal length, and the pawl at the standpipe is tripped by merely closing the circuit by means of a switch, in the engine room of the pumping station. The mechanical operation of the apparatus was perfected by Mr. S. W. Harris, the engineer first in charge at the pumping station, since which time no difficulty has been experienced in shutting the gate at will, from the engine room.

The following year a duplicate of this apparatus was connected with the standpipe at Janesville, Wisconsin.

The practical difficulties attending this method have been found to be first, the necessity of sending a man to the standpipe to open the gate whenever closed ; second, the tripping mechanism is so delicate as to be operated sometimes by electric storms.

Neither of these objections are serious when compared with the benefits derived from the ability to close the gate at will ; but yet were sufficient to lead the study, resulting in the second method, whereby the gate is controlled, or can be both opened and closed at will, from the pumping station.

The first device for this method was put in two years ago at Marion, Ohio, where the distance between the standpipe and pumping station is three and three-fourths miles by the pipe line. In this case, the inlet is also the outlet pipe, and is 16-inch diameter.

The device consists of a 16-inch gate, operated by hydraulic pressure, inserted in the main pipe line between an ordinary gate at base of standpipe and another gate in the street. This hydraulic gate, and water cylinder rests on its side and is an ordinary "Chapman," bell end, hood gate, with composition covered steel piston rod and stuffing box, instead of screw spindle, with 10-inch composition lined cast iron cylinder, connected to hood of gate, by a suitable yoke, the piston used is of the same type, as that for ordinary hydraulic work, and is fitted with hydraulic packing, (double leather cups). All hydraulic work, outside the body of the gate built by the "Deane Steam Pump Company" of Holyoke, Mass. Each end of the hydraulic cylinder was tapped for one-quarter inch pipe, and when ready for work was connected with corresponding ports of the operating valve, which latter occupies the same relation to the working of the hydraulic cylinder as the steam chest does to the steam engine ; the intake port of this valve was connected with the 16-inch main by two lines of three-quarter inch pipe, one on each side of the 16-inch gate, each line being fitted with gate and check valve and the lines being united before reaching the operating valve ; the object of this double connection being to utilize the pressure in the main pipe line on that side of the gate where it should be the greater. It

will be seen that by throwing the pressure through the operating valve, into the end of the cylinder next to the gate, the gate will open, while if the pressure is applied to the other end the gate will close ; the exhaust being back through exhaust ports in the operating valve.

This operating valve was designed by A. H. Howland, Civil Engineer, and consists of a cast iron shell, composition lined, of about two inches interior diameter, and having transversely of the cylinder, five ports one-quarter inch wide, one for the inlet, two for the operating, one connecting with each end of the hydraulic cylinder and two exhaust ports. On a one-half inch valve stem are three brass pistons, three-eighths inch thick, so arranged that a movement of the valve stem of five-eighths inch, will divert the pressure to the operating port at one end of the cylinder and cut off the exhaust at that end, while the same motion will shut off the pressure, and put the operating port and exhaust in connection at the other end.

The pipe used was three-quarter inch reduced at the operating valve and at the hydraulic cylinder to one-quarter inch. Under these conditions and with a standpipe pressure of about 45 pounds the 16-inch gate opens or closes in 45 to 50 seconds.

In order to light the pumping station, and also to furnish means of controlling the operating valve, there was erected at the pumping station a small, high speed, vertical steam engine, of five horse power and an arc dynamo capable of the same effort. At the operating valve was set a lifting magnet, capable of lifting 200 pounds. This magnet consisted of two pair of spools, set in a cast iron frame, above which was attached a rocking arm, carrying at each end a heavy bar of soft iron ; the motion of this rocker arm necessary to bring either bar of iron in contact with its own particular pair of spools, was about one-quarter inch ; on top of this arm was attached another, of sufficient length to give the proper length of stroke to the operating valve, with which it was connected by a rod and bell crank. An insulated copper wire, (No. 8 B. W. G.) was run from each pair of spools at the lifting magnet, (two wires required), to the switch board at the pumping station, where a three way switch set on the center, cuts the electric current out from both wires ; set on either side, diverts the current to and through the pair of magnet spools wired to and connected with that point, instantly attracting the bar of soft iron attached to the rocker arm and thus moving the operating valve as desired, and through that the main gate.

Shortly after the erection of this apparatus, a duplicate was erected at Decatur, Alabama, and during the two years that have since ensued, the magnets at either place, have never failed to respond to the application of the electric current at the switchboard at the pumping station ; in fact the engineer at Marion, states that by actual trial he has found it impossible to make and break the contact so quickly as to fail to work the magnet and valve. During these two years the valves have been operated at least twice each week, to make sure that connections were perfect, valves in working

order, etc., but the magnets have never worked except when the current was turned on to them at the switchboard.

The only difficulty developed in operating has been that the hydraulic cylinder was not large enough to overcome the drag of the gate upon its seat in starting to open it, if the pumps were stopped and full standpipe pressure thrown on one side of the gate ; as, however, this was easily remedied by slowing down the pumps till the pressure became the same as that of the standpipe, and operating the gate while it was thus balanced, no practical difficulty has been experienced ; while to guard against isolation of the standpipe in case of a burst on the long force main, the hydraulic gate is "by-passed."

In building new it might be desirable to construct the hydraulic cylinder of the same diameter as the gate itself.

It was complained at one time that the gate opened quicker than it closed, but an examination developed the fact that this was apparent rather than real, the closing not showing on the gauge till the gate was nearly shut, while its effect was noticeable in opening to the same extent, but in the first case at the end and in the latter case at the commencement of piston travel.

It should have been mentioned that the electrical apparatus was designed and furnished by the "Thompson-Houston Company."

The success of this second method of securing direct pressure has been such that it can be confidently recommended wherever it can be applied. If in a city where there is always maintained a 24-hour electric service, the expense of steam engine and dynamo could be avoided.

If all machinery is standing still at time of the alarm, the engine and dynamo can be running full speed before the main pumps will be ready to "speed up," and whether running or not can all be ready to respond to the call of the Chief of the Fire Department by the time he can get upon the ground and determine that he wants direct pressure.

There are no patents on the combinations by which this result has been secured.

THE VENTURI METER.

BY

R. A. Robertson, Jr., Civil Engineer.

The problem of the commercial measurement of large quanties of flowing water has for a long time resisted all efforts made by hydraulic engineers toward its solution. Positive mechanical meters, reciprocal or rotary, hardly applicable to streams of diameters over four inches, fail utterly when diameters nearing one foot, or quantities nearing one million gallons daily are reached.

Many methods have been devised to this end, but in every case the cost of construction and setting of the cumbrous apparatus employed, the expense of maintaining them and the care required in their use, the loss of head, and the general inaccuracy of the results obtained, have been such as to prohibit their use. Even the weir, recognized as the standard means of measuring water in large quantities for tests, can only be used under conditions in close imitation of those under which the apparatus has been standardized; this too, at the expense of a considerable amount of head, and with a heavy cost in setting and maintaining.

That an instrument, to be available for this purpose, must be both cheaply constructed and maintained at small cost, is necessitated by the low value of the water gauged; it must also operate without serious loss of head. Its action must be continuous, and its indications automatic.

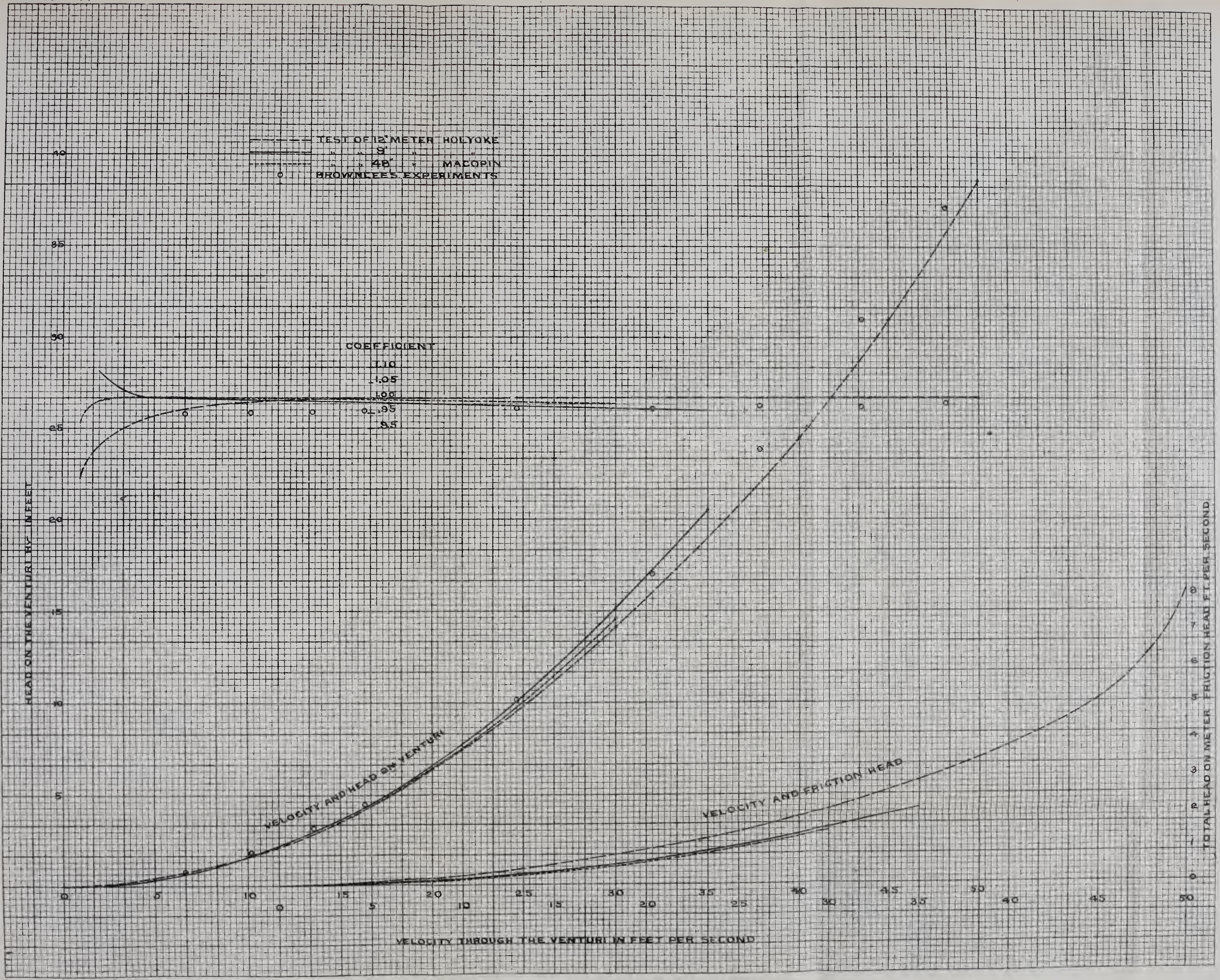
For such a means of measuring water in large quanties, there has grown a demand not to be stifled by repeated failures; and, when at the meeting of the American Society of Civil Engineers, December 1887, in presenting his paper "The Venturi Water Meter; an instrument making use of a new method of gauging water, applicable to the cases of very large tubes and of low value only, of the liquid to be gauged" he made public a solution of this problem, and described careful, severe and satisfactory tests carried on here in Holyoke,—it is not strange that Mr. Clemens Herschel's confrerers should appreciate this eminent engineer's success, and award him the Howland prize for his invention.

Mr. Herschel has very aptly given to his invention the name of "Venturi Meter;" for it was the Italian philosopher Venturi, who, about an hundred years ago, first called attention to the peculiar movement of fluids flowing through converging and diverging tubes, and made known the results of a series of experiments relating to this subject.

Since Venturi's time, a host of scientific men have studied the laws covering the flow of fluids in converging tubes, and varied are the applications made of their discoveries; but it is to Mr. Herschel's honor that of all these scientific men, he alone saw the practical application of these laws.

The meter itself is of extremely simple construction. It consists of a contraction to be introduced into a pipe-line, to produce an abrupt depression in

DIAGRAM A.



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the hydraulic gradient, from the measurement of which the quantity of water flowing can be accurately determined.

In Mr. Herschel's experiments, gauges or piseometers were connected with the meter, one at the throat or smaller section, and one at some convenient point at the up-stream side of the contraction. The difference in pressure indicated by these gauges was the head on the meter. Substituting this head in the simple formula $V=\sqrt{2gH}$, where V represents the velocity through venturi, and g the velocity attained by a falling body in one second, a co-efficient approximating to 1 was obtained. The co-efficient showed a remarkable constancy, whether applied to a rough meter and nine foot pipe, or a smooth meter and one-foot pipe, with velocities through the pipe ranging from one foot to six feet per second.

Measurements with weirs are only to be made by practical repetitions of the Lowell experiments of Mr. Frances. Taking only weirs without end contractions and with depths on the weir ranging from three-tenths of a foot to two feet, the co-efficient or flow varies seven per cent.

In the case of the two meters previously mentioned, so different in size and structure, with areas in the ratio of eighty-one to one, and frictional surfaces widely differing, the combined range of co-efficient did not equal this figure for velocities measuring from five to fifty feet per second through the venturi. During the entire test of the larger meter, in which none of the defects existing in the other had been corrected, did the co-efficient found from a single experiment depart from the mean by more than one-half of one per cent. The precise conditions of every day practice were attained in the tests of the four foot meter at the Macopin intake of the East Jersey Water Company. Here the water was run through the meter, set permanently in the pipe-line, in quantities varying from the rate of two and one-half to fifty millions of gallons per day, thus providing quite a severe test.

Despite the radical changes of form and proportion, the performance of this meter not only confirmed the deduction arrived at from the other tests, but by the increased uniformity and closer approximation of the co-efficient to 1 justified the changes made for the better guidance of the water, and of obtaining precise pressures.

Mr. Herschel also made series of experiments on a one-inch meter, the results of which, notwithstanding the imperfect gauges used, correspond nearly with the Holyoke experiments. Mr. Herschel's experiments receive a most interesting confirmation in those of Mr. James Brownlee, who gave the results of his experiments in a paper read some years ago before the Institution of Engineers and Ship Builders in Scotland. These results, though obtained from a tube whose throat was only .1982 inch diameter coincide almost exactly with those obtained by Mr. Herschel for the one foot meter. This confirmation of the theory is particularly valuable, in that it was obtained by men who never heard of one another, and who followed out different lines of investigation, on tubes varying widely in size and in details of construction.

Dependent as its operation is solely upon the principle of the relation between velocities and pressures, the scope of this form of meter would appear to be very great. Certain it is that the metering of any quantity of liquid up to one hundred and fifty millions of gallons per diem is now easily within the compass of a single instrument, with but the probable error of one-half of one per cent. An instrument too, that is of such simple construction as to cost but little more than its own length of the pipe which it will displace, weighing less, and at no part exeeding the latter in diameter. Without moving parts its durability is insured, and its repairs will form no item of expense ; sticks, dirt, fish, or any other foreign matter which would seriously derange the action of an ordinary meter, will pass the venturi without disturbance. As has been said, one might raft logs through a thirty-six-inch meter, without injury.

The one foot, four feet and nine feet meters, above referred to, were of wood, built up inside a metal tube, and lined at the throat with brass.

Diagram A. illustrates the performance of these three meters. The results of the experiments of Mr. Brownlee are also plotted on the same diagram.

The illustration Fig. 1 represents a thirty-six-inch meter, designed for the East Jersey Water Company, to measure the supply of the City of Newark, N. J. It is made entirely of cast iron and swept smoothly to the required shape. The throat is lined with brass, and the pressure at the head or up-stream end is taken from an air-chamber around the body of the tube above the beginning of the cone, and connected with the interior by clearly drilled holes. The throat is surrounded by a similar chamber, and vent holes in it are drilled in the same plane, perpendicular to the axis, and with clean sharp edges.

The rounding of the up-stream intersection of the cone with the cylinder, of this meter as compared with the Holyoke meters, and the greater smoothness of the cylinder and the superiority of the metal surface over the wood, will contribute materially toward reducing the friction and consequent loss of head, and will also produce a greater uniformity of flow, and increase the precision of the indications.

The length of the meter is about ten and one-half times the diameter of the trunk. One to nine has been taken as the ratio of the area of throat to that of the pipe, and where the loss of two or three feet of head is of no consequence, it will be best to use that ratio ; as with high velocities through throat of meter, greater accuracy and uniformity is obtained, but the instrument can be varied in any or all of its proportions to suit specific requirements, and when it is not important that the meter should measure a wide range of quantities it can be so proportioned that the maximum loss of head shall not exceed one foot.

With the maximum velocity which is allowed in pipe-lines by good practice, say six feet per second, there will be a velocity of fifty-four feet per second through the throat of a meter whose ratio is one to nine. The loss of head when passing this quantity will not exceed ten feet. The loss of head falls rapidly as the flow is reduced. With a flow of five feet per second through the

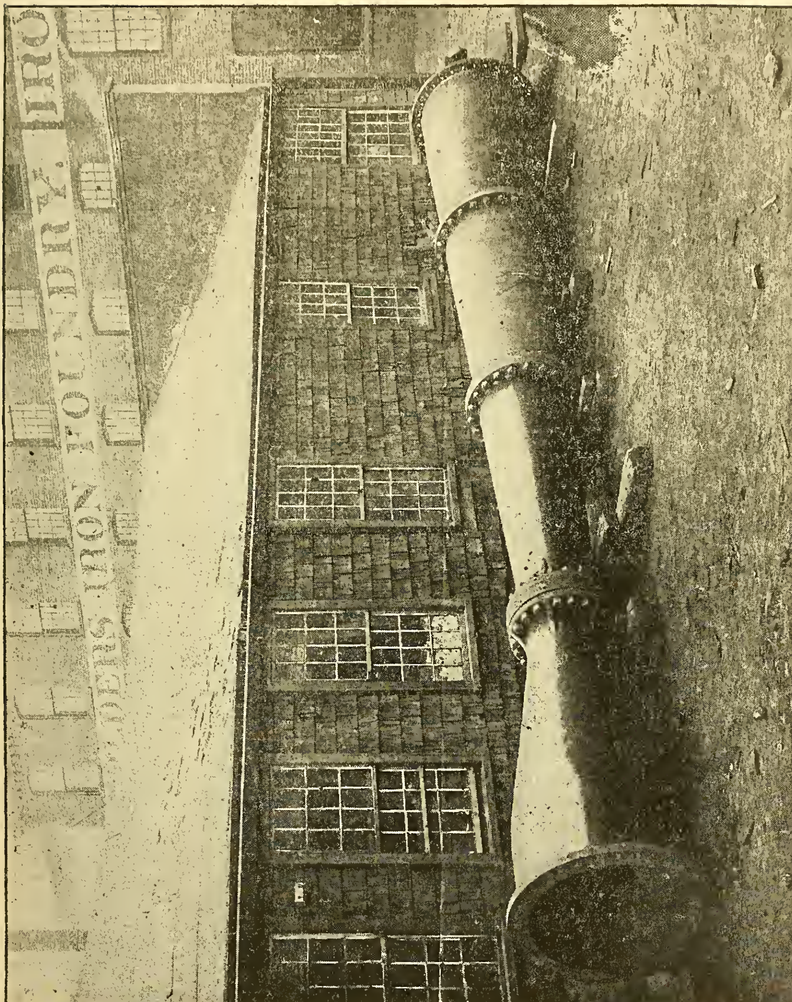

Fig. 1.

pipe, and a corresponding velocity of forty-five feet, through the throat of meter, the loss of head will not exceed four and one-half feet.

In ordinary water works service the velocity in pipe lines seldom exceeds four feet per second, corresponding to a loss of head due to the meter of less than three feet. For almost any case other than for water supplied to mills for power, this friction-head can be easily afforded.

Diagram Fig. 2 shows the loss of head due to friction in Venturi meter for velocities through throat ranging from 0′ to 50′ per second.

It cannot be claimed for the meter that it will successfully operate for very low velocities. The fundamental principle of its action precludes this ; but those velocities of which the measurement is below the scope of this instrument, are equally outside the pale of practice. By the use of very sensitive gauges, measurements of extreme accuracy can be made, and this meter be employed to advantage in tests in place of weirs ; and, as it requires less care in setting and operating, its range of variation is much less. But the commercial success of the meter for use in mains is dependent upon the employment of some instrument which will indicate the amount of water passing at any time, and record the total quantity that has passed.

To devise a satisfactory indicating and recording instrument to do this, has been a very serious practical problem. Mr. Herschel devised several, which, while most ingenious, yet presented some mechanical defects. Several instruments, more or less ingenious, have been successively developed by other engineers, and at length all mechanical defects seemed to be eliminated ; but still, all the recording instruments of this class were radically defective, in that none possessed the power to indicate *at a glance* the quantity of water that had passed.

Mr. H. D. Pearsall, of London, England, suggested the use of an ordinary house meter, to be set on a bye-pass pipe leading from the up-stream connection to throat of meter. The flow through it would be proportional to the flow through the venturi, and, if properly rated, its dial should indicate the volume passing through the meter.

Mr. Pearsall has patented the use of this arrangement. While it is a distinct improvement over all other instruments previously mentioned, it seemed, after careful investigation, liable to failure.

The long sought for instrument has at last been found in an invention of Mr. F. N. Connet. This instrument, for which a patent has been applied, is diagrametrically shown by the accompanying illustration Fig. 3.

In a loop of pipe connecting the throat and up-stream end of meter is inserted a gauge-column of non-conducting material, and a closed reservoir containing mercury. The gauge-column is of sufficient length to permit the mercury, as it is displaced from the reservoir and rises in it, to balance any difference of pressure that may at any time exist between the throat and up-stream end of the meter.

Through the shell of the gauge-tube wires are inserted, each of which is

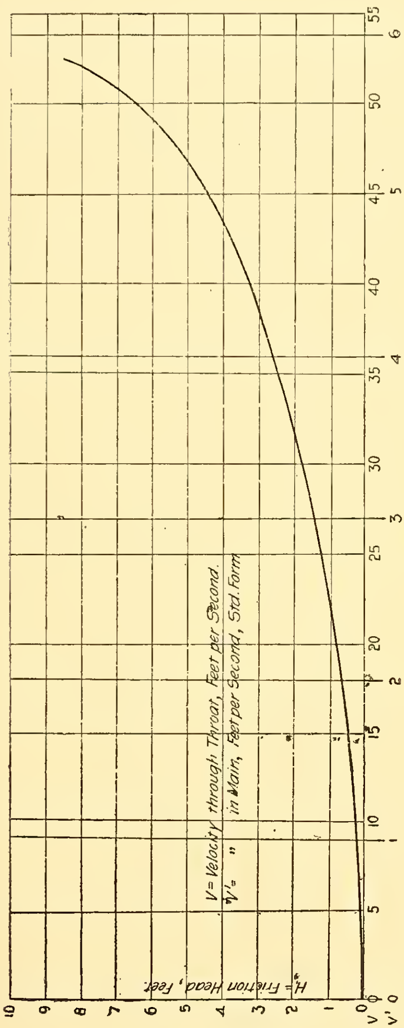
V = Velocity through Throat, Feet per Second.
V' = " in Main, Feet per Second, Std. Form.
H_f = Friction Head, Feet.
0 5 10 15 20 25 30 35 40 45 50 55
0 1 2 3 4 5 6
0 1 2 3 4 5 6 7 8 9 10
V
V'

FIG. 2.

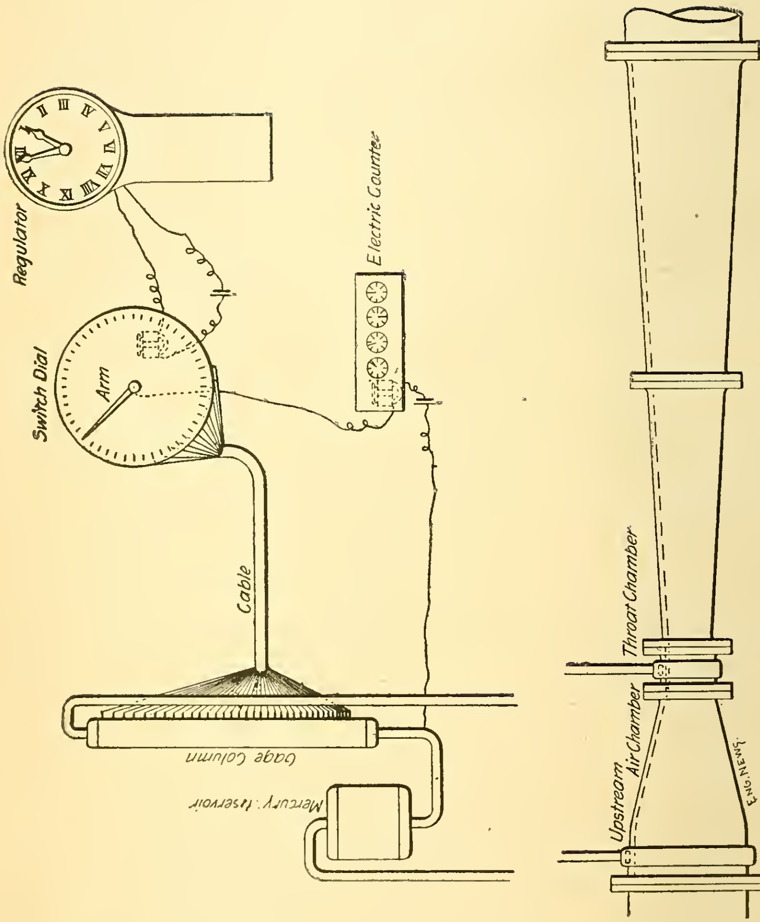
Regulator
Switch Dial
Arm
Electric Counter
Cable
Gage Column
Mercury Reservoir
Throat Chamber
Air Chamber
Upstream
Eng. News

Fig. 3.

connected with one or more buttons spaced about the periphery of a switch-dial. An arm is made to revolve over the face of the switch-dial, and is connected to the mercury in the gauge-tube by wire, through a counter and battery.

The velocity of flow in the throat of meter is determined, as stated before, from the excess of pressure at the up-stream end over that at the throat. In this instrument, this head on the venturi is indicated by the difference between the level of the mercury in the reservoir and that in the tube. The conductors inserted through shell of tube are spaced in such a manner that the number in contact with the mercury is always proportionate to the velocity of flow through meter. The switch-arm revolves at a constant rate, and in one revolution touches every button on switch-dial. There will be as many circuits made and broken, and indicated by the counter, as there are contacts with the mercury in the column. The readings of the counter, then, are directly proportional to, and indications of, the rate of flow through the meter.

With the sectional area of the throat and times of revolution of the switch-arm known, the train of gearing in the counter is made such that a positive volumetric record is made of the flow. The counter adds up the flow for successive cycles for an indefinite period; its dial reads in feet or gallons. The switch-arm may be driven either by powerful clock-mechanism or by an electric regulator clock. These, with counter and batteries, may be placed at almost any distance from the meter. The mercury column, for convenience, may be placed at a very considerable distance from the meter.

Fig 4 shows the switch-dial-case, mercury-reservoir and column, as prepared for slipping into shield-case. Fig. 5 shows the appearance of the apparatus as ordinarily set up, except that, as before stated, the recording-dial may be placed at any distance from the other parts of the instrument.

This particular recording-apparatus was made to accompany a sixteen-inch meter, furnished to the town of Montclair, N. J., in which the maxium velocity of flow through throat does not exceed twenty-five feet per second,—roughly corresponding to two and one-half million gallons in twenty-four hours. A variation of two one-hundredths of a foot in head on the venturi was readily indicated, though such accuracy is not necessary in a recorder of this class, because the intervals between conductors inserted in the gauge-column, which are made to correspond to increments of one-fourth of a foot in velocity through throat, above four feet, are greater than this. The mimimum flow through meter is about five feet, though the recording-instrument is arranged to indicate flows as low as three-fourths of a foot per second.

It is, however, likely that the readings of velocities below two and one-half feet per second would be somewhat in error. As the meter in question is never expected to measure such small quantities, the action of the recording-instrument is interesting only as showing what it might do.

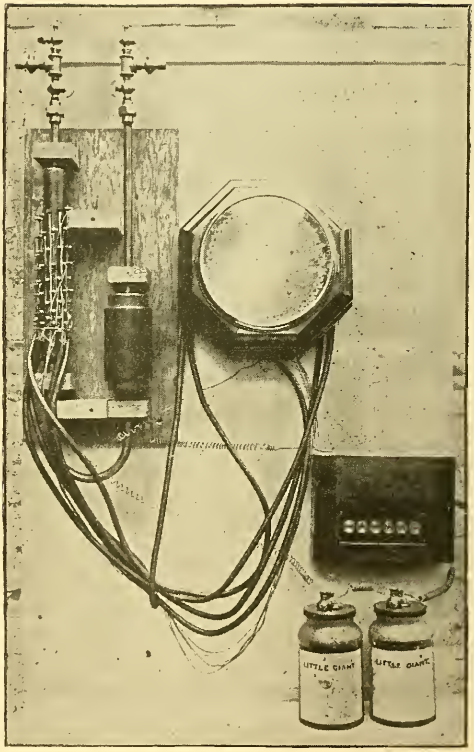

Fig. 4.

The following table indicates the difference in level of mercury in reservoir and tube, when in contact with different conductors, together with the velocity of flow through throat of meter corresponding to such contacts :

Number of Contact Point.	Vel. in Ven. ft. per sec.	Cu. ft. per sec.	Rise of H. g. in tube.	Head on Venturi ft. of Water.
1	$\frac{3}{4}$	.116	.007	.0091
2	1-$\frac{1}{2}$	.232	.028	.036
3	2-$\frac{1}{4}$	.348	.064	.082
4	3	.464	.114	.146
5	3-$\frac{1}{2}$	.542	.115	.198
6	4	.620	.202	.259
7	4-$\frac{1}{4}$	.659	.228	.292
8	4-$\frac{1}{4}$	.698	.256	.328
9	4-$\frac{3}{4}$	.737	.285	.365
26	9	1.396	1.024	1.31
44	13-$\frac{1}{2}$	2.094	2.304	2.95
62	18	2.792	4.096	5.24
63	18-$\frac{1}{4}$	2.831	4.211	5.39
80	22-$\frac{1}{2}$	3.49	6.400	8.19
81	22-$\frac{3}{4}$	3.53	6.543	8.37
89	24-$\frac{3}{4}$	3.84	7.744	9.91
90	25	3.88	7.882	10.108

This kind of recording apparatus possesses many interesting features that are not at first apparent. It automatically integrates any variation due to violent fluctuation of flow, and records only the mean flow. Should any refinement of accuracy be required, or further experiments make it seem desirable, the position of contacts in gauge-column can be changed so as to correspond to minute variations found in co-efficients for any particular meter, from zero to maximum flow. The experience gained from the experimental and commercial meters that have been made is such as to warrant the declaration that the Venturi meter will measure large volumes of fluids or gases far more accurately than they can be measured by any other means, and that its adoption is no longer attended with any trouble, uncertainty or risk.

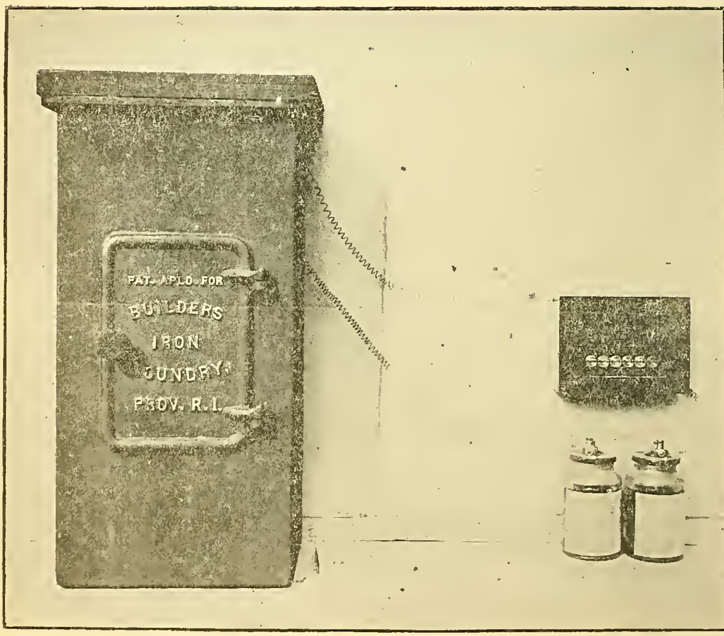

Fig. 5.

DISCUSSION.

Mr. Richards. It seems to me that this meter is going to be very valuable for works supplied by gravity. Where the water is supplied by pumping, the consumption can be found with reasonable accuracy from the pump records, but when the works are supplied by gravity it is a hard matter to arrive at definite details regarding the consumption, and that is something it is always very desirable to know. It seemed to me, however, from the reading of the paper—I should not want to make the statement until I had digested the paper somewhat—that under very high velocities the loss of head would be very considerable in the meter. In the case of the ordinary flow in the supply mains it would probably record it very correctly and with a loss of head easily spared, and it is possible that there might be some attachment, a by-pass or something of that kind, to relieve the meter when there was an exceptionally heavy draft. It seems to me that would be necessary. But the meter appears to be a very valuable instrument.

Mr. Robertson. I will say in reply to Mr. Richards' remarks that those who are engaged on the commercial side of the Venturi meter are very much interested in the problem Mr. Richards suggests, the correct measurement of the quantity of water pumped. The hope is that the Venturi meter will be serviceable in that direction, and we are already in correspondence with a water works corporation for the manufacture of a very large meter for this purpose, to check up and detect leakages in the pump. Mr. Richards raises the point of the loss of head in the meter with high velocities in the main pipe. The velocity through the throat of the meter as ordinarily constructed is about nine times the velocity of the flow of the water in the main pipe, and with a velocity of six feet in the main pipe the maximum loss of head due to the meter will not exceed, as I said in my paper, 10 feet; but it seldom occurs in water works practice that a velocity approximating to six feet in the main pipe is reached. If it is, and it is a long pipe, it is high time the corporation had a larger pipe.

Mr. Stearns. I would like to ask Mr. Robertson if he has computed what the length of pipe is that that loss of head would compare with.

Mr. Robertson. I haven't followed it out, but it is a very easy problem to work out.

Mr. Stearns. I presume it would only represent the friction in a certain limited length of pipe in any case.

Mr. Robertson. That is it. If you noticed, in my paper I said the details of the meter might be varied in every way. In cases where extreme velocities are to be contended with the diameter of the throat of the meter may be increased, and in such a way as to very materially reduce the loss of head due to the meter. For instance, the throat may be made in the ratio of 1 to 3 instead of 1 to 9, or even 1 to 2, and still record accurately. The laws governing its action are just as positive with the small contraction, but with a large throat the accuracy of the measurement of small volumes

may be in error. But where we have to contend with high velocities in a main pipe we are seldom called upon to contend with very *low* velocities, and the reduction of the throat from 1 to 9 was made to cover as wide a range as possible to meet ordinary requirements.

Mr. Fuller. I would like to ask Mr. Robertson whether this meter can be put in a pipe line and some recording apparatus connected with it so it can be told month by month what the consumption is. And I would also like to ask him regarding the expense of such an arrangement.

Mr. Robertson. The meter is covered up. It is intended to be put in the ground and to form a part of the pipe line. It is entirely out of sight and beyond attention.

The recording apparatus may be placed at any distance, miles, if need be, from the meter. The reservoir and gauge tube containing the mercury should be placed within some reasonable distance. say 500 feet, but there is no limit to the distance to which that the switch arm and recording instrument may be carried. For instance, the meter may be placed at the reservoir on the hill, and the recording apparatus in the Commissioners' office miles away.

With regard to the expense, I am not posted on the prices for ordinary meters, but my impression is that the Venturi meter, even so small as six inches, can be furnished for about one-half what the ordinary meter of six inches is sold for. But we do not propose to come in contact with the meter people on such small sizes. We keep away from them entirely, so that they may have that field to themselves; we want to keep on good terms with them.

Mr. Fuller. Wouldn't this be a good way to measure the water used for fire service in large mills?

Mr. Robertson. There is no reason why it shouldn't be used. We are in hopes it will be adopted for that very purpose, not only for fire supply for mills but for railroad service. There seems to be a very good field in that direction; and also in measuring large volumes of gases or heavy fluids.

Mr. Richards. The reduction on a 20-inch main would be to somewhere about six or seven inches and that seems at first thought rather alarming.

Mr. Robertson. It does seem appalling at first sight to reduce a 20-inch main to six or seven inches, but if a gauge were put on the meter above the reduction and another one below the reduction, it follows by an absolute law that the pressure will be reduced only by the amount shown by the curve on the diagram. It cannot be otherwise.

Mr. Noyes. I would like to ask Mr. Robertson how low velocities the meter will gauge accurately.

Mr. Robertson. Ordinarily not below five feet per second through throat of meter, which corresponds to one-ninth of five feet per second in the main pipe. If it is required to measure very small quantities the gauge I spoke

of in my paper can be so constructed as to follow the variations of the coefficient discovered for any particular meter. In such a way I have no doubt that velocities as low as two feet per second in the Venturi could be measured accurately; and if that were not satisfactory a special meter could be made with a much smaller throat than the standard meter. A meter will be seldom called upon to measure both the greatest quantity that can be made to flow through a pipe and quantities as low as those suggested by Mr Noyes. Ordinarily the requirements are between reasonable means, and the meter can be constructed to meet those requirements.

Mr. Noyes. Then in a case such as Mr. Richards spoke of, of a gravity system, where the night consumption is very small and the day consumption quite considerable, it would not give a correct history of the consumption.

Mr. Robertson It is possible that the night consumption will exceed the mimimum of the gauge. I think the night consumption would never fall below, for instance, a half a foot per second in the main pipe.

Mr. Fuller. I wish you would inform me why we could not have a series of different sized meters on a by-pass.

Mr. Robertson. That might be arranged, of course, but one would probably do all that is required.

Mr. Richards. You think it would not make a record below half a foot a second?

Mr. Robertson. It would make a record, but the record might be out of the way to an extent of four or five per cent. It would still be within the range of an ordinary meter, however.

Mr. Noyes. Approximately how close will it record as you reduce your velocity?

Mr. Robertson. Probably within five per cent. with a flow through the Venturi of one foot, corresponding to an inch and a half in the main pipe. The diagram illustrates that. The more accurately the meter is made the more accurate will be the measurements.

John Thomson, M. Am. Soc. C E. Mr. Robertson's paper; which while in many respects most interesting and evidently carefully prepared, starts off with statements more or less misleading. Of these I first note the assertion, laid to the door of other meter makers that their instruments are "*hardly applicable* to streams of diameters over *four inches* (and) *fail utterly* when diameters nearing one foot or quantities nearing one million gallons daily are reached." It appears sufficient to say respecting the foregoing that the yearly output of at least five companies in the United States will reach hundreds of positive displacement meters of the four and six inch capacities and that the practical experience with nearly all large sizes of meters is quite as satisfactory as with the smaller capacities, for the good reason that the range in rate of delivery is more constant and the velocities to be dealt with are lower. There is at least one company in the United States that for some time have been making positive meters up to ten inches capacity, while another company also makes meters

up to the same capacity but of the inferential type. In Great Britain the "Kennedy" has long been built in the eight and the ten inch sizes, a meter by the way which has never been excelled in point of accuracy of measurement. Then, of the current or velocity meters, a type common in Europe, may be mentioned Tylor's, Siemen's and the "Universal" each of which is made in sizes up to twelve inches capacity. If these have "failed" utterly (because of their size) then I would like to have the evidence, even although such proof would militate against the high opinion which I have had reason to entertain for many of my competitors in this branch of engineering.

Again, referring to one of the paragraphs regarding Mr. Herschel, this averment is made, that "of all these scientific men, he alone saw the practical application of these laws." Mr. Herschel's admirable accomplishment was to ascertain a co-efficient, by the employment of exceptionally favorable conditions coupled with accurate, painstaking observations, which resulted exactly as might have been predicated in view of the well known principles upon which the demonstration was based. All honor to the "prophets" of our own country, but not to the detriment of the prophets who have gone before. Properly disposed there is honor enough for all and to spare.

As to the design of the Venturi tube, I am inclined to the opinion that the already nearly constant co-efficient would be yet slightly improved if the throat were extended to form a short *cylindrical* tube, the lower piezometer being connected several diameters away from the converging inlet. The presumed advantage of this cylindrical section would be to ensure as solid a stream in the section of the higher velocity as in the section of the lower velocity, as it is probably impracticable to construct the internal surface of the "Venturi" with such theoretical accuracy as would be necessary to entirely avoid variable contraction of the jet, due to velocity where it enters the throat.

In regard to the recording mechanism, which by the way, is really all there is to a system of this kind, (once having ascertained the co-efficient,) I should say that Mr. Connet's device is probably as accurate as any that has been suggested, and in meters of large capacity, under charge of competent assistants, ought to give a good account of itself. But for any general use, subject to the usual care and attention which is regarded "good enough" for meters, it can hardly be looked upon as commercially practicable. In the early days of multiplex telegraphs I had some experience with "make and break contacts," which resulted in a somewhat settled opinion that the doctrine of chances seemed to favor "that tired feeling" to which such contrivances are occasianally subject. Much of the success of this register will depend upon the arrangement and conditions under which the electrical apparatus operates; which is not fully set out in Mr. Robertson's description. Thus, for instance, it would appear desirable that the mercury circuit should be operated by a weak current acting through a relay to the motor magnet, etc. But considering all the conditions, the ample loss of head available for motive purposes, say, as

stated, from four to ten feet, and the slight variation in rate of flow. I see no reason why a modified arrangement analagous to that credited to Mr. Pearsall, or shown in my brief paper on a Proportional Water Meter, presented to the American Society of Civil Engineers, June, 1891, would not serve the purpose satisfactorily. In such an application the meter mechanism is in fact but a motor employed to drive the register which may either indicate the total volume or the aliquot part which passes there through. Such an experiment might now readily be made and the result compared with what has otherwise been accomplished. And I can say that the state of the art is such that but little difficulty would be found in making such an application without interfering with prior patented arrangements Nevertheless, irrespective of the means by which a record may be obtained of differential pressures whereby to denote the volume of water flowing under pressure, it is my opinion that any system short of complete positive control of the entire quantity, will leave a feeling of uncertainty; because under such conditions we deal with the *inference* of the fact, not with the fact itself.

WATER SUPPLY AT FIRES.

BY

John C. Haskell, Superintendent, Lynn, Mass.

Thinking that the experience of Lynn during the fire of November 26th, 1889, would be of interest to the Association, I take this opportunity to present it.

The population of Lynn as given by the census of 1890 was 55,727. Our average daily consumption of water for the year 1889 was 2,450,413 for the week previous to the fire was 2,339,263 gallons.

The supply from which we drew was furnished from a reservoir containing at the time the fire broke out 20,510,872 gallons, a Leavitt engine of 5,000,000 daily capacity which was in operation at that time and the Marblehead Water Company which is connected with our works. The reservoir is situated about two miles from the point where the fire started.

The ordinary water pressure through the burnt district is from 60 to 70 lbs. The water was supplied from the reservoir and Leavitt engine to the burnt district through one-16″ and two-12″ mains. The burnt district was intersected by streets supplied with pipes as follows: one 12″, five 10″, three 8″, four 6″, eight 4″ provided with 35 hydrants.

While it is impossible to give any accurate statement of the number of streams playing at the same time on the fire, the whole number of engines at work was 19 and the amount of water used from 12 m. November 26, the time the fire started, till 6 p. m., was 2,908,477 gallons; from 6 p. m. on the 26th to 6 a. m. the 27th, 5,373,282 gallons; from 6 a. m. till 12 m. on

the 27th, 2,827,736 gallons; making a total consumption in 24 hours of 11,109,495 gallons.

The burning debris required a farther use of water amounting to 19,376,-984 gallons, making a total consumption of 30,486,479 gallons used for all purposes from the commencement of the fire until the consumption of water reached its usual amount.

The amount used each 24 hours was: First 24 hours 11,109,495 gallons; second 24 hours 7,338,703; third 24 hours 5,313,290; fourth 24 hours 4,325,621; fifth 24 hours 2,399,370 gallons.

At the commencement of the fire it was so evident that a conflagration would ensue that every effort was made to stop any waste of water. Men were sent out with instructions to shut off the service pipes and fire sprinklers as soon as a building provided with one was well on fire. As far as possible all waste from this source was removed.

One 4-inch elevator pipe was broken outside the shut off and one 4-inch fire sprinkler was wasting water until 8 and 10 a. m., November 27th, at which time respectively they were shut off. The delay in shutting off these pipes was caused by the bricks from the fallen walls covering the gates.

From our experience at this fire it is evident that a city of our population, favorably situated to receive assistance from other cities, is liable to be called upon to furnish a supply of water greatly in excess of the full capacity of its own Fire Department and equal to four times its ordinary daily consumption. This additional supply may be required for several days. In our case the amount of water stored in the reservoir, together with the constant work of the Leavitt Engine, enabled us to supply all water needed without being obliged to start the Deane pump which could have been added had it become necessary.

Although our works could have furnished much more water than we were required to, a Loietz Pumping Engine of 10,000,000 gallons daily capacity has been substituted in place of the Deane and we can now pump 15,000,000 gallons per 24 hours should the necessity arise.

An additional 20-inch main is now being laid from the reservoir to the center of the city. When this work is completed we will be able to supply for 24 hours six times our daily consumption.

The loss of water through a 4-inch fire-sprinkler from 3 p. m. of the 26th until 10 a. m. on the 27th shows the danger that menaces any water supply should the introduction of fire-sprinklers become general.

The weakest point in our supply of water for fire purposes is an insufficient number of hydrants in the business portion of the city.

THE ARRANGEMENT OF HYDRANTS AND WATER-PIPES FOR THE PROTECTION OF A CITY AGAINST FIRE.

BY

JOHN R. FREEMAN, Civil Engineer.

In March, ~~1879~~ 1880, I presented to this society an account of some experiments upon nozzles and fire-hose. We will at this time consider the problems presented next farther up the stream and discuss certain matters relating to the hydrants, the water mains and the magnitude of the water supply. The following questions arise:

1st. What is a proper allowance in gallons per minute for a good fire-stream?

2nd. What is a suitable pressure?

3rd. How many streams ought our works to be able to supply simultaneously?

4th. What relation will this additional supply available for fire bear to the supply necessary for ordinary consumption?

5th. In what position and at what distance apart can the hydrants be most advantageously placed?

6th. What sizes of pipes will be necessary to convey the above determined volume of water and deliver it at the required point with an efficient pressure?

7th. Having given a plan showing the lengths, diameters and elevations of the pipes of a given water-works distribution system, how can we compute the gallons per minute or the number of fire-streams which can be delivered at a given point?

Considering the foregoing questions in detail:

1ST. GALLONS PER STREAM:

The writer considers it best to base computations on 250 gallons per minute for a standard stream.

In the ordinary fire in a residence district, and perhaps for more than 19 out of 20 of the fires to which even the department of a large city responds, the actual average delivery does not exceed from 175 to 200 gallons per min-

ute, but this is for fires brought quickly under control and fought mostly at short range and in which but a small part of the full power of the department is exerted.

The efficiency of a waterworks or a fire department, is measured by its ability to control a bad fire before it becomes a sweeping conflagration, and our design should be based upon streams suitable for this purpose.

I have heard the opinion advanced at some of the meetings of this society that 150 or 175 gallons was a fair allowance—and statements by men who stand high can be found giving 200 gallons per minute as proper.

No doubt these may have been fair average values of actual draft at the ordinary fire with the apparatus common ten years ago, but the point which I would emphasize is, that such values are wholly misleading and unfit for use in designing a system which is intended to cope with the extraordinary fire and to hold it from sweeping through the city.

Experience shows that large streams are much more effective on a fierce fire than small streams. A small stream may be so completely evaporated into steam as it passes through the flames as to never reach the seat of the fire.

A fire cannot be extinguished by wetting the flames.

In every fire which makes a flame, there are two processes taking place—the first process is the roasting out of gas ; the second is the burning of this gas.

Water extinguishes mainly by chilling the ignited surface so no more gas is given off – the flames then die.

With a large stream, even though half the water be evaporated as it passes through the flames, there may be enough left to quench the glowing coals which form the heart of the fire.

Thus we see the reason for the opinion which many practical firemen have been led by experience – that given, say, 1,200 gallons of water per minute under good pressure—this will do more good on a fierce fire if concentrated into four $1\frac{1}{4}$ in. streams of 300 gallons each, than if used in six 1 in. streams of 200 gallons each, or ten $\frac{3}{4}$ in. streams of 120 gallons each.

The controlling element in the size of fire-streams is the limited diameter allowable for the hose.

A $1\frac{1}{8}$ in. 250 gallon stream calls for a velocity of 16.34 feet per second in the hose.

This velocity is far beyond what in other arts is regarded as the economical limit for the velocity of flowing water.

In city water mains from 2 to 3 feet is the common velocity—in sewers the same is true—in the flumes supplying turbine water-wheels 3 to 5 feet can seldom be exceeded with propriety, and in the short delivery pipes to low lift centrifugal drainage pumps, 10 feet per second is the common maximum.

In fire-hose we are held up to high, force-wasting velocities by the all important necessity of keeping the hose so small in diameter and weight that men can grasp it firmly, handle it easily, and move it around quickly.

Practical experience has settled on $2\frac{1}{2}$ inches internal diameter as the favorite size.

The latest advices from Pittsburg where 3-inch hose was tried, would indicate it to be unwieldy. My own opinion now is that the hose of the future will be $2\frac{3}{4}$ inches in diameter, still for many years we must consider $2\frac{1}{2}$ inches as the standard size.

To deliver 250 gallons per minute with only 3 feet per second velocity would require a hose or pipe nearly six inches (5.83) in diameter.

In other words, *you force as large a volume of water through a $2\frac{1}{2}$ in. hose as would go through a six inch pipe at the 3 foot velocity common in water mains.*

We want as large a fire-stream as we can get and can handle.

A $1\frac{1}{4}$ in. stream is used in many departments and is often better than the $1\frac{1}{8}$ inch, if water is plenty and length of hose short. If hose is long, the friction due pushing so much water through so small a pipe leaves the nozzle pressure so small that the stream is too feeble.

Thus from the hydraulic principles involved, we find that with hydrant pressures of 80 to 100 lbs., and lengths of hose from 200 to 400 feet, the $1\frac{1}{8}$ in. nozzle is the size best adapted for all-round use with $2\frac{1}{2}$ in. hose.

On the other hand, from the teachings of practice and without any discussion of scientific principles, the $1\frac{1}{8}$ in. smooth nozzle has come to be the size most common in the best American fire departments.

A smooth nozzle becomes an excellent water meter if the diameter of its bore and the pressure at its base be known, so *if it be admitted that a $1\frac{1}{8}$ in. stream is the proper size and that a pressure of 45 lbs., at the base of the nozzle is needed to throw it in good shape to a proper height and distance, it follows without room for question, that 250 gallons per minute is a proper allowance for each stream.*

A $1\frac{1}{4}$ in. smooth nozzle under 41 lbs., indicated nozzle pressure will discharge 300 gallons per minute.

At almost any instant during a large fire, a part of the streams will be momentarily stopped, as for instance to enable position of hose to be changed; moreover some streams will be working intermittently, holding fire from spreading, extinguishing the incipient flames as they catch on combustible cornices and roofs.

The writer has been an eye-witness of several very severe fires and has each time been struck with the sadly deficient power of a large proportion of the streams; conversely, he has watched with admiration the quenching effect of a $1\frac{1}{4}$ inch stream at two extremely hot fires; and as Hydraulic Engineer to an Association of Insurance Companies, has studied the character of streams in many trials of factory and city apparatus, and has come to be very strongly of the opinion that the following values are none too large for a safe basis for estimates.

For a severe conflagration in a residence or suburban district, 200 gallons per minute may serve well.

In the midst of the business part of a great city, as in the dry goods district of Boston or New York, 300 gallons per minute is the safest basis for designs.

For a general average value, we believe 250 gallons per minute to be abou right.

In our own experience we have found it very common for the statements of the number of streams in use at one time to be too large and on following up the matter closely have found for instance, that although eight lines were run out, not more than six were in active use at any one time, we therefore feel that the smallness of the recorded average delivery is often due to an error in the number of streams, and from studying several severe fires, as an eye-witness, I have come to believe that it is much too often the case that the stream delivered by the nozzle is too small or too feeble to do good service.

Many and many a time more than half the static hydrant pressure is wasted in overcoming the friction through too long a line of hose or too small a street main.

A proper question to ask when considering any record as to the average gallons per stream actually used at a fire is—Were the streams found to be of the size adapted for extinguishing the fire?

Without positive affirmation on this point the statistics may be misleading or worse than useless as data for determining the proper allowance.

2ND. WHAT SHALL WE ADOPT AS A STANDARD NOZZLE PRESSURE WHEN DESIGNING A FIRE SUPPLY?

The great majority of fires with which the well trained firemen of our large cities contend, are fought from the inside and at short range and for such work a nozzle pressure of 20 to 30 lbs. is well enough, but although 49 out of 50 fires can be thus extinguished, our design should not rest here but should be planned to bring under control one of those greater fires which once each few years, in some unexplainable way, gets a furious start and threatens to cut a swath through the town.

These greater fires must be fought from the outside, and often with the hose men standing on the ground.

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1. At the great "Thanksgiving Day Fire" in Boston, the 86 streams thrown during tho hottest of the fire averaged 233 gallons each, according to the estimate of the engineer of the Boston water works, (See Journal, N. E. Water Works Association, 1890, p. 182.

At the Collier Lead and Oil Works' fire (loss $81,000) in St. Louis, as reported by the water commissioner, (M. L. Holman, C E. in Journal Eng. Soc. 1882, p. 112.) The average delivery of each stream was estimated at 337 gallons per minute but this is unusually large and subject to question by reason of the computation being apparently based on an assumption that the steamers played 1⅜ inch jets with a pump pressure of 200 pounds per square inch.

2. In Fanning's Treatise, Water Supply Engineering, p. 506, the supply for a fire-stream is estimated at 150 gallons per minute. (Later in his address before the National Water Works Association, May 1892, Mr. Fanning bases his estimates upon a good standard for a small city, a 1⅛ inch stream discharging 281 gallons per minute.)

J. Herbert Shedd, C. E., bases his estimates on 200 gallons per minute as a fair average allowance. (See Journal N. E. W. W. Association, 1889, p. 91.)

Mr. Wm. B. Sherman, C. E., of Providence, Journal N. W. W. Association, p. 91, 1889, is authority for the statement that at one of the most severe fires ever experienced in Providence, (Sept. 27, 1877, loss $362,000,) twenty-five streams were used and the average draft shown by pump records was 189 gallons per minute.

Mr Wm. R. Billings of Taunton, in Journal N. E. W. W. Association, p. 105, cites two large fires in Taunton, where in one case, the streams averaged 130 gallons per minute, and in the other, 150 gallons per minute, as shown by the records at the pumping station.

In a compactly built district we must be able to wash sparks and incipient flames off from the highest roofs and cornices, and we must be able to deluge a building that is already ruined past value, as a means of safety to its neighbors, and to the middle of a wide one-story warehouse or among lumber piles, we must be able to throw a far reaching stream.

Although too often lost sight of in discussion, high pressure to span a broad distance is often as necessary as to carry a jet high. Occasionally it happens that a pipe-man would be almost roasted alive if he stood much nearer than 50 feet to the building in flames.

I have sought to learn the working pressure most suitable as a standard to base designs upon by experiments on jets from various sizes of nozzle and with nozzle pressures all the way up to 100 lbs. per sq. in. and have studied the matter as best I could at several fires.

From 40 to 50 lbs. pressure at the nozzle is that which I have finally come to consider as about right.

More pressure than this can be obtained for occasional need, by siamesing two lines of hose into one ordinary $1\frac{1}{4}$ inch nozzle and thus saving three-fourths of the pressure commonly wasted in friction between the hydrant and the nozzle.

In the determination of the greatest allowable pressure, we are limited somewhat by the recoil which the man at the nozzle can hold.

An inexperienced man of average strength will have all he can do to hold and move around a $1\frac{1}{8}$ in nozzle under 25 or 30 lbs. pressure.

An experienced man can manage a $1\frac{1}{8}$ in. nozzle under 40 lbs. pressure very well.

Nearly always at a fire two men have hold of any nozzle from which a stiff stream is being played and can hold anything under 50 lbs. quite easily.

In order to present a clearer idea of just what a 45 lb. $1\frac{1}{8}$ in. jet will do, the sketch below is presented.

Suppose a bad fire in the fourth story of a five story commercial building.

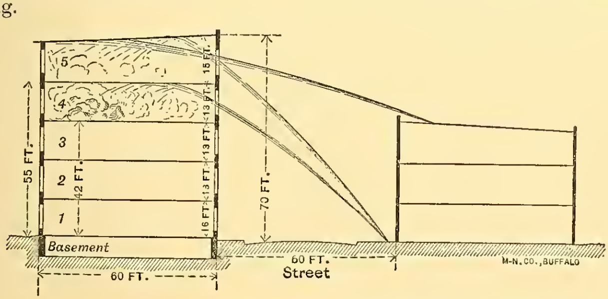

Fig. 1. Diagram representing the force of a 45 lb. x $1\frac{1}{8}$ inch jet.

A good fireman would, of course, use every effort to gain an entrance to fight it at short range, quench it around the entrance and thence work back

through the room, but suppose special circumstances made this impossible an that it must be, for a time at least, worked from the ground.

Now if there were a water tower at hand, this might pour a deluge into the upper stories, but only cities of more than 200,000 inhabitants commonly possess a water tower.

A $1\frac{1}{8}$ or $1\frac{1}{4}$ inch stream with a nozzle pressure of 40 to 45 lbs., would just about suffice to pour in streams through the upper windows as sketched, so they would strike the ceiling with such force as to be well scattered, and by concentrating from 2 to 4 such streams against any given sash for a moment, it could in all probability be burst in.

NUMBER OF STREAMS.

The third question with which we started was:

How many standard fire streams should the water works of a given city be able to supply all at one time?

This is a hard question to answer definitely and that it is unsatisfactory to formulate a rule based on population or area or valuation alone is evident when we consider how the fire hazard varies with:

1st. The compactness with which the city is built, the presence or absence of broad streets lined with shade trees which furnish in summer excellent fire screens.

2nd. The presence or absence of great concentrations of value.

3rd. The presence or absence of centres of special hazard such as wood working factories, lumber yards, oil works, etc., surrounded closely by compact rows of woodon structures.

4th. The prevalent structural material, whether wood or brick.

5th. Situation upon the shores of a body of water so that streams from steam fire engines can conveniently take the place of hydrant streams from the water works.

6th. Most potent of all in controlling the decision is the question of cost and of the inability to meet the additional expense which the furnishing of each additional stream entails.

7th. A burning business block fifty feet square by three stories high demands just as many fire streams to extinguish it and to protect the buildings each side of it when it happens to stand in a village of 2500 inhabitants as when it stands in a city of twenty times that population, but the larger city can provide the greater number of streams without feeling so severely the burden of the expense.

The question, therefore, comes down to getting as near 10 streams for a fire district with close-lying valuable buildings and having 10,000 inhabitants or less, or as near 30 streams for a city of 100,000 inhabitants, as can be had without burdensome expense.

There may be large villages where broad streets and ample yard room make the conflagration hazard small, in which if the expense attending an installation is unusually large, it may be true economy to proportion its pipe lines and means of supply to yield only 2 or 3 standard streams and to

let the owners of isolated, special hazards, find their further safety in insurance.

On the other hand, if a community depends for support mainly upon some group of factories whose destruction might paralyze the life of the town, and if there was a cheap and convenient source of supply, it might be decidedly best for a village of 5000 inhabitants to provide for 10 (250 gallon) fire streams, although this is double the ordinary allowance for this population as shown by the table below.

But after all, though there may be exceptions, as above noted, communities of the same population average pretty much alike in size of leading buildings and in general compactness of the centre of the town.

As a rough, general guide, the writer presents the table below :

Total population if community protected:	No. of 250 gallon streams which should be available simultaneously in addition to maximum domestic draft:
1,000	2 to 3
5,000	4 " 8
10,000	6 " 12
20,000	8 " 15
40,000	12 " 18
60,000	15 " 22
100,000	20 " 30
200,000	30 " 50

Ten streams or as large a proportion thereof as the financial consideration will permit may be recommended for a compact group of large, valuable buildings irrespective of a small population.

So far as a general statement may apply, we should say that the pipes should be large enough and the hydrants numerous enough so that two-thirds of the above number of streams could be concentrated upon any one square in the compact, valuable part of the city or upon any one extremely large building of special hazard.

Mr. J. Herbert Shedd, was the first, so far as the writer is aware, to formulate the number of fire streams needed in proportion to the population. (See Journal, N. E. W.W. Ass'n,. March, 1889, p. 113.

Mr. Shedd there presents a formulae and a diagram, showing the number of streams needed, from which the following values are taken:

Population.	No. of 200 gallon streams.
5,000	5
10,000	7
20,000	10
40,000	14
60,000	17
100,000	22
180,000	30

The population above given to be estimated on the same basis as that which the works are intended to serve.

The above table is of special interest coming from an engineer af Mr. Shedd's experience.

Mr. Shedd cites a few cases to confirm the above from good American practice, as follows :

(a.) In his own practice in designing water works. he states that for a population of 8,000 he has provided for throwing six streams at any point within the fire district.

(b.) At Bridgeport, an intelligent committee carefully looked into the question of fire supply and decided that thirteen streams should be provided for a population of 40,000.

(*c.*) At Fall River the greatest rate of fire draft shown by pump records (Dec. 8th, 1874, Am. Print Works Fire,) was 2,600 gallons per minute, equivalent to 13, 200 gallon streams. Population at that time 45,000.

(*d.*) At Worcester the greatest number of streams ever used at a fire was understood to be 18. Population 73,000.

(*e.*) At Providence, at fire Feb. 1888, Mr. Shedd thinks it probable 22 streams were used. Population 120,000.

In Journal of New England Water Works Association, Mr. Dexter Brackett calls attention to the fact that at the fire of Nov. 28th, 1889, nearly double the number of streams which this rule of Mr. Shedd's would call for, were actually used, viz., 86 streams of 233 gallons each were used. Mr. Brackett further says that "the area covered by this fire was small [3½ acres,] and I see no reason why a similar fire might not occur in any smaller city containing high buildings on narrow streets."

Since preparing this paper we have been pleased to note the conclusions of the eminent hydraulic engineer Mr. J. T. Fanning, who gives in his address before the American Water Works Association the following table:

Population.	Fire Streams under about 54 lbs , nozzle pressure.
4,000 to 10,000	7 to 10
10,000 to 50,000	10 to 14
50,000 to 100,000	14 to 18
100,000 to 150,000	18 to 25

Better than by data based on population, the question of the number of streams which it should be possible to concentrate at any one point, as well as the question of the total number of fire streams to be provided for the city, can be best solved by a tour around the given city, studying out the spots where a large number of streams would be needed to check a conflagration which may be conceived to have so got beyond control as to hold some one of the largest buildings in flames from top to bottom and from end to end.

The liability of two fires in progress at the same time in one fire district, must be recognized, and allowance for the breaking off of the small service pipes extending into the buildings wrecked, must also be made. The equivalent of one or two good streams may easily be thus wasted. (There have been cases where a small public supply has been rendered utterly useless by the breaking, in the early stages of a fire, of a 3 in. or a 4 in. pipe entering a building.

As a means of avoiding the wasting of water and weakening of pressure which follows the breaking of a very large service pipe (2 inch, 3 inch, 4 inch or upward) a device similar to Fig. 2 may be used.

The essential feature is a permanent wrench F A whose handle A is conspicuously located two or three feet above the level of the ground, so as to avoid the delay of hunting at night, perhaps, for a service gate-box covered by dirt or snow and located no one knows exactly where.

The particular form shown in Fig. 2 also makes it plain to all passers by whether the gate is open or closed.

A permanent gate operating post like this can often only be placed at the curb-stone line. Thus located it is no more of an obstruction than a hydrant or a lamp-post, but might be found so near to the fire that it could not be operated. It could be made always accessible with certainty and safety, by placing it at the opposite side of the street, to do this the service would

make a loop with a quarter bend each side the gate, and cross back under the main pipe.

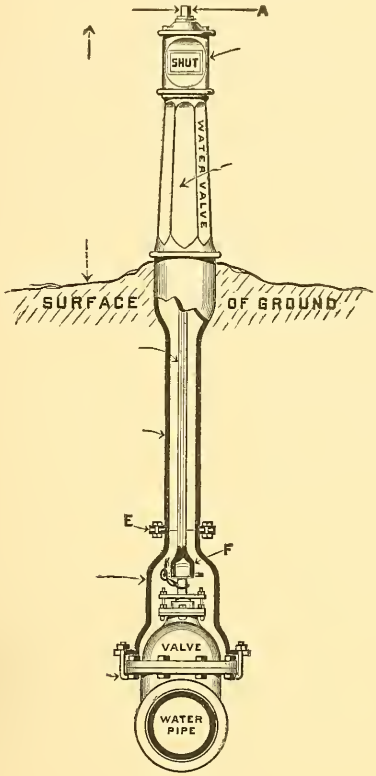

Fig. 2.

4TH. RELATION OF THE FIRE SUPPLY TO THE VOLUME OF WATER NEEDED FOR THE ORDINARY SUPPLY:

The fire supply decides the size of the distribution mains.

The domestic draft in any given district to say $\frac{1}{4}$ mile square, is but a small fraction of the possible fire draft.

The domestic draft of a town is distributed with approximate uniformity over its area.

Pipes for domestic supply alone might start with main arteries and taper down to small veins at the extremities of the area. Fire protection often demands concentrating all the water which a system can furnish at one point and this one point may happen to be almost anywhere.

It is in one case *distribution*, in the other, it is *concentration*, and in planning many works this principle of being able to concentrate the full supply at one point has not been recognized and the branch mains are too small.

A single good $1\frac{1}{8}$ *in.* $\times$ 45 *lbs.* $\times$ 250 *gallon fire stream takes as much water as would be needed on the average for the ordinary domestic supply of a population of six thousand,* (at 60 gallons per day to each person.)

It is the common experience of water works where complete pump records are kept or where there is other means of noting the hourly flow, to find that the maximum draft, (as for instance during two or three hours on Monday morning), or in a suburban district, for an hour or two about sunset in summer when everybody is watering his lawn) is double the mean draft for the 24 hours. (Sometimes it is $2\frac{1}{2}$ times the average consumption for the year.)

A sufficient fire supply should be provided *in addition* to this maximum domestic consumption; but in cases where to supply each additional fire stream involves an expenditure which cannot well be met, it is not unreasonable to take some chances that the worst kind of a fire will not start at the hour of maximum consumption, and thus one might scale down somewhat on the estimate given on the previous page.

Still this maximum rate of domestic draft, viz., double the average draft (or of whatever ratio of increase the actual record, if there be a record, may show for the district under consideration,) should always be kept in view as *the basis over and above which the fire supply is to be secured.*

A somewhat mistaken feeling of security sometimes arises from an exhibition of the number of streams which can be thrown from newly installed works before the domestic draft has fairly begun, and I have seen officials deceive themselves in testing a direct pumping system by first taking two or three hours to get a fresh, bright fire under the boilers and to get the standpipe full, and to get everything in readiness for an exhibition.

CAPACITY OF ELEVATED RESERVOIRS FOR FIRE PROTECTION.

With an elevated distributing reservoir forming part of the system, it becomes a much simpler problem to provide the large surplus flow needed for fire protection than when the surplus must be rapidly forced through a very long pipe, since but little if any larger conduit between the source and the distributing reservoir over that suitable for the maximum domestic draft need be provided, and but little if any greater pump capacity is needed than that which will without regard to fire protection be provided as a precaution against break downs.

The elevated distributing reservoir also gives the very great advantage that at the outbreak of a fire the extra delivery can be supplied the instant the hydrants are opened, without waiting to fire up another boiler or waiting to throw extra pump into commission and without any of the possible derangements of electric alarms, or the possible derangement of machinery incident to the excitement of speeding up in response to a fire alarm.

If the reservoir can give a pressure of 80 to 100 lbs., it possesses a great advantage in promptness and available volume and cost of maintenance over any ordinary equipment with steam fire engines.

The storage capacity for fire supply in a reservoir, need not be so very large for although the rate of draft may be high, the duration is short.

In isolated, private plants for the protection of large factories, it is the common practice of the Factory Mutual Insurance Companies to ask for, as the least allowable supply, water sufficient for *one hour's draft of the full number of fire streams* which it is designed to supply simultaneously and that when fire pumps are fed from cisterns, these should be large enough to supply the pumps for at least one hour running at full speed.

For the protection of a city, the requirement is much greater, for although all questions as to the destruction of the building in which the fire starts can commonly be decided inside of an hour after the full number of streams are playing, the fire may meanwhile have spread to other buildings and from these the sparks may have been carried to still others.

In a conflagration lasting nine hours, very likely the total draft of water would be no more than equivalent to six hours at the maximum rate.

One million gallons storage will supply eleven standard fire streams for six hours, and for the ordinary city up to 15,000 inhabitants, a million gallons could therefore be considered an ample and prudent reserve of storage for use in fire.

To take the number of streams given in the table on page 55 and consider them as drawn for six hours, would now appear to me to be a reasonable basis on which to decide the maximum allowance for fire protection in an elevated reservoir supplied through a long conduit, or by surface water or springs.

If on the other hand the reservoir (or standpipe) can in an emergency be fed by reserve pumps, then it might be that one hour's supply for the full number of streams could be regarded as ample, and as margin enough to cover the interval while starting the reserve boilers and pumps.

The above mentioned volumes of water might be small under circumstances which it is possible to conceive, but in this whole matter we must commonly steer a difficult course between burdensome expense on one hand and more or less remote possibilities on the other.

Against the more remote of the possibilities it is true economy to "run for luck" and put out trust in insurance to distribute a possible loss.

Such records of actual draft in time of fire as we have been able to find, although interesting, are too incomplete to found a rule upon.

Sometimes a small draft will apparently have sufficed for a large fire, when in truth the reason that the fire was so large may have been that the supply of water was so small, or again an extra large draft may have been due to the opening of so many hydrant streams that the pressure was so drawn down by friction through inadequate mains, that the jets, though big enough, were too feeble to reach the heart of the fire.

The total volume used may vary greatly according to whether the firemen shut off the streams as soon as there is no more good they can do, or keep them playing as long as steam rises from the ruins.

CITY, FIRE, DATE, HOUR OF ALARM.	POPULATION IN FIRE DISTRICT.	PRINCIPAL AUTHORITY.	VALUE IMMEDIATLY HAZARDED.	LOSS.	MAX. RATE OF FIRE OVER OR'NARY DRAFT	MAX. NO. OF STREAMS AT ONE TIME.	DURATION OF FIRE UNTIL FULLY UNDER CONTROL AND NEARLY OUT.	AREA BURNED OVER.	TOTAL FIRE DRAFT GALLONS UNTIL FULLY CONTROLLED AND NEARLY OUT.	METHOD OF SUPPLY	REMARKS.
					gal. p.m						
Boston — "Thanksgiving Day," Nov. 28, 1889.	400,000	D. Brackett, Jour. N. E. W. W. Asso. June, 1890, p. 182.	Many millions in heart of Boston dry goods district.	About $4,000,000	20,000	86		3½acres	14,000,000	Steamers from large mains fed by gravity.	Water enough was thrown to cover burned district 12½ feet deep and fire did not get beyond the buildings to which it had spread during the first hour.
Boston—Great Fire, Nov. 1871.											
Lynn — Great Fire, 1889. Began at noon. Uncontrolled 6 hrs.	55,700	J.C.Haskell	Whole central business portion of city.	About $5,000,000	About 6,700	About 20 hose str. & 2 broken 4 in. pipes.	From 6 to 9 hours.		About 3,000,000	St'mrs from hydrants fed by Res. and large pumps.	
St. Louis — Collier Lead Works.		M J.Holman		$81,000	3,375	10					
Providence-Sept.27, 1877.		W. B. Sherman.		$362,000	9,500	25					
Providence — "Aldrich House" fire Feb. 15, 1888.		J. H. Shedd. W. B. Sherman.			4,400	22			2,000,000		
Fall River — Am. Print Works, Dec. 8, 1874.		J. H. Shedd.		$17,600	2,500	* 25			488,000		*Looks as though there might be an error, the gallons per stream is so small.
Fall River—Border City Mill			Nothing but what was burned.	$450,000 Total.	2,400	11			3,035,000		Loss nearly as complete and swift as though no water supply had existed.

The above table, though incomplete and unsatisfactory as data, is presented in the hope that it may encourage statistics in regard to future fires at which the water supply is in charge of members of this Association.

DISTANCE AND POSITION OF HYDRANTS.

In many cities the street hydrants are too far apart and there are too few hydrants around the centers of value.

The arbitrary and not altogether reasonable custom of basing the compensation which the water works receive for its fire protection, not on value protected or on cost of works, but solely upon the number of hydrants, and establishing for the use of each hydrant an annual rental which on an average, equals the total cost of buying and setting a hydrant, has had much to do with keeping hydrants too far apart.

If the statement which has been made, that take the average of American water works, the hydrants average one to 800 feet of pipe, is true, then it might almost be said that an extra hydrant ought to be put in between every hydrant now present and its neighbor.

It is true economy to be generous in the number of hydrants and thus to save money on the outlay for hose and for making good its annual depreciation.

Moreover, by the use of short lines of hose, there is a great gain in the efficiency of a stream by the increased force of the stream, its greater volume and the greater height and distance to which it will reach.

Good jacketed fire hose now costs about seventy-five cents per foot.

A six inch tar-coated heavy cast iron main can be laid for about seventy-five cents per foot, cost of pipe, trench, lead and laying all included.

A city can buy a good two-way hydrant for less than the price of 50 feet of good fire department hose and its water department can buy and put down 100 feet of the best six inch cast iron water pipe for just about the same price that its fire department pays for an equal length of hose.

The life of the hose will not average more than 5 to 10 years. The pipes may last 50 years.

The bed-rock facts on which our rule for spacing hydrants must rest, are that *a good, stiff* $1\frac{1}{4}$ *inch stream cannot be delivered through a greater length than* 300 *feet of good, ordinary fire hose, unless there is more than* 100 *lbs. pressure at the hydrant.*

And that *a good, stiff* $1\frac{1}{8}$ *inch standard stream of* 250 *gallons per minute cannot be pushed through more than* 400 *feet of even the very best and smoothest hose by a hydrant pressure of* 100 *lbs.*

The water works giving a hydrant pressure of more than 100 lbs. are comparatively few, and the liability of accident is so increased that it is as a general rule advisable not to exceed 100 lbs. hydrant pressure.

The average New England pressure is only about 75 lbs., therefore if one would use hose lines more than 300 feet long, he must sacrifice in the power or size and the efficiency of the jet, or must use a steam fire engine to give it an extra push.

Even with the best ordinary steam fire engines a really good stream can rarely be obtained in ordinary work at the end of 600 feet of hose while working at its rated full delivery in gallons.

A seven-hundred-gallon-engine may do it when playing only one 250 gallon

stream, or rarely may do it with two streams under expert treatment at an exhibition.

This limit to the length of hose through which a good stream can be forced, indicates that as a rule there should be hydrants enough around or near to any very important block of buildings in a city of moderate size without steamers and with 80 to 100 pounds hydrant pressure, so that eight hose streams could be led to it without the average line of hose being more than 300 to 400 feet in length and with no one of these eight lines more than 500 feet in length.

Too often the idea has apparently been to arrange the hydrants so that no important building should be more than 500 feet away from some one of the hydrants or to arrange things so one or two streams could be put on any building. *The true idea is, to so far as practicable, arrange things so that the whole power of the water works can be concentrated on any one building—and this by no means involves such expense as one might expect before investigating.*

Perhaps as good a rule as any, providing the pipe sizes and the supply are adequate, would be to take the table on page 55 as a basis, and require such arrangement of the hydrants as would permit this whole number of fire streams for a small city or two-thirds of the whole number for a large city, to be concentrated on any one large and important block of buildings, with an average length of hose not exceeding from 300 to 400 feet, and with no line much over 500 feet, this being on the basis of 80 to 100 lbs. hydrant pressure.

If steam fire engines are used, a few of the lines may be 600 feet long.

If hydrant pressure is but 60 to 70 lbs. then the hydrants should be so placed with reference to any important building, *that half the whole number of streams could be drawn through lines of hose not exceeding* 250 *feet in length.*

The above refers, of course, to large buildings or to the closely built part of a community.

In an outlying residence district where one building does not hazard another, two powerful streams in one building would nearly always be enough.

At least two 2-way hydrants giving four streams should however, be always provided, partly so that one hydrant may be available though the other is deranged or frozen.

(This ever present possibility that a hydrant may be deranged or frozen is not only a strong reason for not stretching them out long distances apart but is a good reason for preferring two 2-way hydrants to one 4-way hydrant.)

As 200 gallon streams or even 175 gallons and 30 lbs. pressure streams would serve fairly well for a dwelling, we could tolerate a spacing that would require a 500 foot length of hose from the house to the most distant of the two hydrants.

Thus in a suburban district containing detached dwellings, the hydrants should seldom if ever be placed over 500 feet apart—400 feet would be a better average—and within a compact commercial or manufacturing district, it may be true economy to place them only 250 feet apart.

We believe there are many communities among those having a water

pressure of 70 to 80 lbs. where 2-way hydrants very near together (200 feet) and large mains could be so arranged as to afford better protection than an ordinary number of steam fire engines and that the annual interest on the increased cost of the larger pipes and the double number of hydrants would be less than cost and annual maintenance of engines, engine companies and extra hose.

It is also to be strongly urged that hydrants be *located on the ground* instead of on a map by spacing off exactly even distances, they can often be moved back and forth 25 or even 100 feet with great advantage or can be staggered first on one side of the street and then on the other, and can thereby be got away from too close proximity to the buildings of special danger.

In the preceding paragraphs we have considered the building which is farthest from the hydrants or the most unfavorably located of any in the square. This being provided for as above, the average building would be served by still shorter lengths of hose.

At nineteen out of twenty ordinary fires, and possibly at forty-nine out of fifty fires, such a liberal number of hydrants would not be needed, but at the six million dollar fire of November 28th, 1889, in Boston's Dry Goods district, it was found of the utmost value for the fifty-two steamers in use to be able to draft the eighty streams from the hydrants and to play through no hose line over 600 feet long, and the fire was held to an area of about 3½ acres on which a volume of water was poured equivalent to flooding it 12½ feet deep.

At the great fire in Lynn in 1889, of which I was also an eye witness, the long lines of hose were of the greatest disadvantage, and after going from point to point studying the fire and the means to control it, my judgment upon the streams being thrown on the fire, was that not one in four could be called a really good fire stream.

A municipal hydrant system needs to be designed for more than the ordinary fire. *It should be designed to cope with the extroardinary fire and to overtake it and hold it in check even after it has got one or two hours start of the firemen*, for even then with the fire department and the citizens aroused, it may prevent a sweeping conflagration.

The percentage of increase in the total cost of a municipal water works needed to enable it to do this, is not nearly so large as might be supposed.

A FEW EXAMPLES IN HYDRANT LOCATION:

To see how the rule which we have devised from general principles, works in practice: 1st. Take a village or city intersected by cross streets, as in Fig 3. Obviously the best places for hydrants are at the street corners, since a line of hose can thence be led off so conveniently in either direction required, and since there is no delay hunting for the nearest hydrant where they are so conspicuously located.

A common size for a city square is about 250 x 550 to centres of streets or with the blocks themselves, 500 x 200 feet, and the following sketch will therefore serve as a fair illustration.

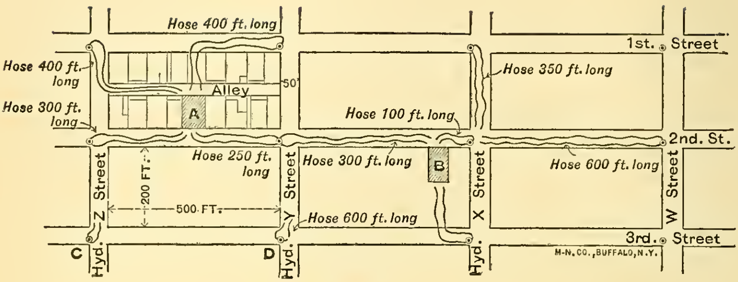

FIG. 3.

Suppose a fire to exist in the building marked A, if the hydrants are all 2-way, we see that with hydrants only at street corners, eight streams can be concentrated upon A and use lines not exceeding 400 feet in length, while four more streams making twelve in all, could be run in from C and D with lines of hose about 550 feet long.

Or for a building near a corner as B :

2 100 foot lines would deliver extra powerful streams.
4 more streams would be had through lines 200 to 350 feet long.
2 " " " " " " " 500 " "
4 " " " " " " " 600 " "
or 12 streams in all.

A skillful fireman would use $1\frac{1}{4}$ inch nozzles on the two 100 foot lines of hose and 1 inch nozzles on the 600 foot lines and $1\frac{1}{8}$ in. on the others.

The foregoing would serve well for the most important buildings that are ordinarily found in a city of up to say 15,000 inhabitants.

The above arrangement is possible only with the most favorable street plan or with rectangular blocks of moderate size and cross streets near together. With a less favorable street plan the hydrants must be placed nearer together and more hydrants must be used.

When we consider a great city and the higher buildings with larger individual floor areas and stocks of greater value which are found therein, and also the greater havoc which a spreading conflagration would entail, a much greater concentration of hydrant streams will be found necessary.

This can be accomplished by placing an intermediate hydrant at the middle of the two long sides of each city square, or by the use of 3-way or 4-way hydrants.

In Fig. 4 for instance, with 2-way hydrants, 22 streams could be concentrated upon F and its neighbors, 12 of which would be through lines not over 300 feet long and none of which exceed 550 feet. And so in almost any case, by a little study, it will be found that the generous supply of fire streams called for on page 55, can be provided for and concentrated without entailing any such burdensome expense as might without investigation be supposed.

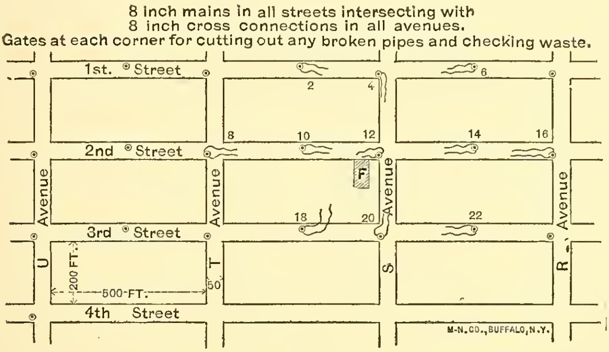

FIG. 4.

As to the hydrants themselves, we believe that a post hydrant having a feed pipe and a riser of ample size can be constructed so as to practically give just as ample a supply of water as a Lowry or other flush hydrant and avoid the complication and bother of carrying a chuck.

A post hydrant moreover, avoids the possible delay incident to finding and digging out a frozen man-hole plate at midnight, from its covering of snow or mud.

And as to the argument that a post hydrant forms a dangerous obstruction at the curb-stone line of the street, and therefore is inadmissable, we fail to see that they are a more dangerous obstruction than lamp posts, telegraph poles or the poles supporting the wires of the electric street railways.

The post hydrant is conspicuous, everybody becomes familiar with its location, and if properly constructed the inspection of a moment will tell whether or not it is frozen.

We do believe, however, that very many of the post hydrants now in the market are susceptible of a little improvement in design which would lessen the friction loss through them, and furthermore, we hold that it is a mistaken economy to set even a 2-way hydrant with less than a 6-inch feed pipe and smaller than a $5\frac{1}{4}$ inch riser.

Four-inch risers should be allowed to die out of the market by neglect.

An eight-inch feed pipe, a six-inch riser and round corners leading to the hose nipple will often be true economy even for a 2-way hydrant where it is desired to use streams direct from the hydrant and where the pressure does not exceed 75 lbs. per square inch.

THE SIZES OF PIPES NEEDED FOR THE DISTRIBUTION SYSTEM OF A PUBLIC WATER SUPPLY, IN VIEW OF FIRE PROTECTION :

Consideration of fire protection generally determine the minimum pipe sizes proper for the distribution mains.

One good $1\frac{1}{8}$ inch stream takes as much water as 3,500 population would draw for domestic purposes, on Monday morning.

The maximum domestic draft of water, thus has little weight in determining the proper size of the distribution mains, although it is the chief factor in deciding upon the size for a long main pipe between a source of supply and the city.

The relative elevation of the source of water supply or the water pressure which the pumps can afford, has much less influence upon the size proper for the distribution mains than might appear at first thought, and it is seldom that any substantial reduction from the sizes mentioned below will be judicious, even though the pressure be high. (As 125 lbs. for instance.)

If high pressure is available (and a working pressure of 80 to 100 lbs. is always well worth securing even at considerable extra cost) this high pressure should not be taken to compensate for small mains but had far better be utilized in permitting hose streams to be taken direct from the hydrant and thus dispensing in large part at least, with the delay and extra expense incident to the use of steam fire engines.

In the opinion of the leading engineers and of the water works superintendents of the widest experience, it is pretty well settled that under ordinary circumstances *nothing smaller than a six inch pipe should ever be laid as a main to supply hydrants.*

Four inch pipe should never be used for a hydrant main, unless it be to protect scattered, detached dwellings in situations similar to a country village or where the closest economy of first cost must be practiced in order to get any general water works pipe system at all, and in these cases it should be clearly understood that starting with say 75 lbs., a line of four-inch pipe one-half mile long so soon as it becomes old and roughened by rust can only deliver water enough for a single 100 gallon fire stream three-fourths inch in diameter, which is too small to extinguish anything more than a dwelling house fire or often can do more than protect the neighbors, while the original fire is left to burn itself out.

In patching up an old water works to make it serve the modern requirements the old four-inch pipe can often be allowed to remain by feeding it at both ends or at frequent intervals by a larger cross connection so that any hydrant on the four-inch pipe will in effect be fed by two four-inch pipes, the water flowing to it in both directions.

A quarter inch in thickness of deposits gathers just about as quickly upon a four-inch pipe as upon a six-inch pipe and it reduces the water carrying capacity in far greater proportion on the four-inch pipe than on the six-inch.

Within a crowded and valuable metropolitan district, a diameter of eight-inch is the smallest that can be recommended for the general net work or "gridiron" of intersecting pipes, having in view the deterioration in water carrying capacity which occurs in time with nearly all waters.

For valuable metropolitan districts a pipe so small as eight inches is suitable only when forming part of a general net work whose intersections are not far apart, say not more than 300 feet in one direction, by 800 feet in the other. When the cross connections are smaller than eight inches or farther than 800 feet apart, a ten-inch pipe may be needed. Along the borders of the gridiron the size should be larger. This reinforcement by cross-connections, is of the utmost importance and if absent as at C, Fig. 5, it may require a 16 inch pipe to afford the same delivery as a gridiron of six-inch pipes at B.

Within almost any suburban residence district where there are frequent cross connections, also within compactly built cities of medium size and even those of large size and of medium hazard, excellent protection may be afforded by a gridiron of six-inch pipes along each of those streets running in one direction, intersecting with pipes eight inches in diameter, in each transverse street. The maximum of economy in pipe will be secured if the six-inch pipe runs lengthwise of the blocks.*

For small cities in which the streets run so that frequent cross-connections are possible, very satisfactory protection can be had by a net work of pipes none of which exceed six inches in diameter; but along the margin of the gridiron there should be a few main arteries of larger sizes and the size of a few of the pipes near any large hazardous building as a valuable factory or warehouse may need be increased.

This use of six-inch pipe, however, presupposes that the six-inch pipe makes a complete circuit about each street block which is to be protected, so that the water will flow in toward the point of heavy draft from nearly all directions.

To illustrate that a complete gridiron of six-inch pipe under a favorable street system will afford a large supply for the hydrants at any one spot, take the assumed case shown in Fig. 5 and suppose a very heavy fire at A.

1st. Suppose the four 2-way hydrants immediately around A all drafting, this gives eight streams with an average length of hose about 300 or 400 feet.

Tracing out the circuit shown by the dotted line nearest A we see that this water flows in toward A through the six or seven 6-inch pipes and the 2,000 gallons per minute delivered by the 8 streams would average but 330 gal-

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* Lawrence, Mass., (50,000 population, engaged principally in cotton manufacture ; dwellings compact, mostly of wood furnishes an excellent example of the use of six and eight inch pipes in this manner. Nothing smaller than six-inch pipe is used, nearly all the pipes running east and west are six inches, and none running north and south or crosswise of the blocks are less than eight inches. The blocks average about 550 by 250 feet to centres of streets. Furthermore, a 20-inch main artery runs from the pumping station down past the large factories to a point midway along the canal, where it is reinforced by a 20-inch main coming from the reservoir down through the heart of the city.

In Boston, the general system toward which the engineers are now working is to cross a given territory by 12 inch mains about one-fourth mile apart, and then gridiron across between these by eight or ten-inch pipes in each intervening street in the compact valuable portion of the city or by six or eight inch pipes in the outlying districts.

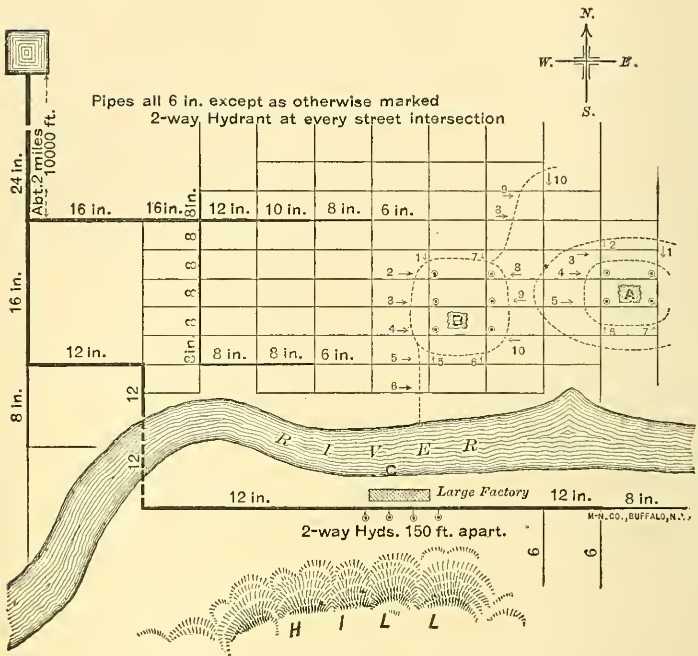

Fig. 5.

lons or about $3\frac{3}{4}$ feet per second for each pipe, calling for a loss of head of about one-half pound per 100 feet of clean pipe or say 1.0 lb. per 100 feet when pipe is somewhat corroded.

Thus the loss of pressure, within a circuit of from 300 to 500 feet around the fire, would not exceed from three to five pounds at most.

Going out to the next circuit shown by dotted line, we see that here are nine pipes pouring their water in toward A so that outside this circuit the velocity averages about 2.6 feet per second and the loss (with pipe a little rusty) about 0.4 lbs, per 100 feet.

As we take wider and wider circuits, we find more and more pipes through which the water is advancing toward the fire.

With a well planned system of cross connections the reduction of pressure under a heavy draft nearly all occurs in the immediate vicinity of the fire.

Thus probably all told, the reduction of pressure which a gauge on pipes near A would show when eight streams were flowing would, speaking roughly, be about 6 lbs. for new pipes or 10 lbs. for old and somewhat rusty pipes, lower than the pressure when hydrants were closed.

A was taken at a point near the outside of the gridiron.

If we had taken the four hydrants around B for illustration, these would have been fed by eight pipes, or had twelve lines of hose been run from the six nearest hydrants, none of these lines of hose would need be over 600 or 800 feet long, and the twelve hydrant streams would be supplied through ten 6-inch pipes.

The above city was assumed to have very frequent cross connections and a very symmetrical system of street mains. In many of our New England towns the hills and valleys have compelled a growth radiating outward in narrow strips or in ways which forbid any such reinforcement or the flow as we have here been considering, and in these cases much larger pipes will, on computation be found necessary to give an equal delivery at the hydrants.

In deciding upon the diameter needed for a street main in a given locality, the possible reinforcement through cross connections and parallels must always be studied if economy is to be secured.

A block located in the midst of a network of 6-inch pipes may sometimes be much more efficiently served than one past which runs a single line of 12-inch pipe. Thus the block B is much better supplied than the factory C. Fig. 5.

The main arteries within the city have often been continued of larger diameter than really necessary after once reaching a point well within the main gridiron system.

Thus in Fig. 5 we see that although the 16-inch main goes but a little way into the city, the distribution does not suffer.

Often the money which these large internal arteries would absorb, can be more advantageously applied in keeping up the size of the secondary mains, or in reinforcing them by well planned cross connections.

THE CENTRAL SYSTEM VS. THE OUTSIDE SYSTEM OF MAIN ARTERIES.

In a system of sewerage or a system of water supply which was to supply numerous buildings and which was not designed for fire protection, the system of distribution, which may be likened to the trunk and branches of a tree, or the veins in a leaf, and consisting of a large central artery feeding smaller diverging arteries and these in turn the distribution pipes in the several streets, would undoubtedly be the most economical to install.

In fire protection,, it is the concentration of a large volume rather than its divided distribution for which we must provide, and the study of a street plan like Fig. 5 will show that the locality which needs a specially large pipe the least, is the central portion of the gridiron where the 8-inch or 6-inch mains pour in their water from every side. Each 6-inch pipe on which stands a hydrant being in effect two 6 inch pipes leading to that hydrant.

Commonly, of course, the central portion of a city is most valuable and needs the most ample protection, but this is not always the case.

In a sea port or a river town, the commerce or the factories often make a marginal street the one where protection is the most important.

On such a marginal street we can get aid from only one parallel street instead of two as in Figs. 2 and 3, and should therefore not only have a large pipe, but an extra number of hydrant outlets, therefore the hydrant locations

and pipe sizes for such marginal streets should always be designed on the principles just described, by taking a plan of the district, marking thereon such number of hydrants, each with such number of outlets as are needed to concentrate the full number of streams thereon without exceeding the hose lengths already stated, and then provide pipes of sufficient area to deliver this withoutundue loss.

Another great advantage of placing a circuit of main arteries half way around the circumference of the gridiron instead of feeding everything from the centre outward, is that as the city extends its borders we shall be in far better shape to give proper protection to the new streets.

A FEW PROBLEMS IN COMPUTING A DIVIDED SUPPLY.

The following is not of general interest perhaps but my reason for presenting it is that men engaged on practical work have presented similar problems and asked how they could best be solved. This is *one* way. Others may have better.

Where a pipe system is complicated so that the flow of water is divided and comes to the given point over several routes, or when the pipes are old, then any precise computation of the friction loss under a very heavy draught is uncertain, very complicated and generally unsatisfactory.

One day's experimenting will often give results more trustworthy than can be obtained in a week of computing. Often, however, the delivery and friction must be known when it is impossible to expeiiment or before the pipes are laid.

There are often cases where the pipe system is simple or where it is of a fairly large size in proportion to the required draught when computations of much value may be easily made.

One great source of uncertainty in computations on pipe which is not new is that the conducting power varies greatly, or with the same size and kind of pipe, and with exactly the same rate of flow in gallons, the friction loss may be twice as great in a pipe which is rough as in another which is smooth.

The mere roughening of the inside of a pipe can double the friction loss even though the size be not diminished by deposits. A roughened surface sets the water whirling, eddying and tumbling over itself in a way which greatly increases the force needed to move it along.

Some waters corrode pipes much more rapidly than others. Thus it is said that in Baltimore even uncoated water pipe remains clean after 50 years of service ; in Boston an uncoated 4-inch pipe may become almost choked up by tubercles in half that time. A properly tar-coated cast-iron pipe will, however, often keep nearly free from tubercles in Boston for 20 years.

GRAPHICAL COMPUTATION OF FRICTION LOSS IN A COMPOUND PIPE.

Case 1.—*Loss in a compound pipe.*—What will be the loss of head, due to friction between A and D in Fig. 6?

A precise and accurate equation to represent this loss would be very unwieldy, and in general it may be said that for problems of this kind, long-

jointed equations are unnecessary and of little practical use, although they are of very great value for training students in the application of algebraic expression, and therefore have a proper place in the text-books.

Short, simple equations and graphical solutions, joined and worked together by process of reasoning, so that a frequent inspection is had of the numerical values of the different elements as we go along, are much more convincing and less liable to the introduction of errors.

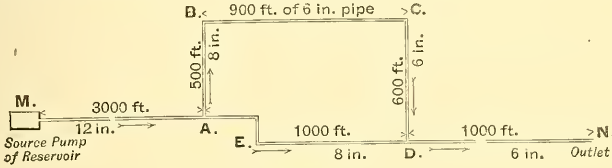

FIG. 6.

For the present purpose we may neglect that variation in the co-efficient of flow which depends upon the velocity being low or high, for the effect of this would be obscured by the greater influence of even such small differences in the smoothness of the interior of some portion of the pipe as are often concealed from observation.

We may therefore assume that the frictional absorption of pressure within any given pipe system varies directly as the square of the quantity drawn through it. With the high velocity of flow common during fire duty, this assumption comes very near the truth.

This general truth—*viz., that the loss of head by friction is proportional to the square of the velocity*, applies not only to a simple pipe, but is substantially true for combinations of pipes of different sizes joined either by taper reducers or by sudden contractions, or for pipes containing obstructions and curves. It is also useful to keep in mind that for cases of a pipe system in combination with a discharging orifice or with a series of discharging orifices, so long as all the discharging orifices lie at substantially the same elevation, the opposite of the above proposition is true and of wide application:

Viz., *the quantity discharged through a given pipe system, and the orifices in connection therewith is very nearly proportional to the square root of the pressure* measured at any convenient point anywhere along the pipe system, providing the pressure be reckoned from the level of the orifices.

As one illustration, take the fire stream tables published in the Journal of the New England Water Works, Association of March, 1889. We see that, taking the same piece of hose connected to the same nozzle, the discharge varies as the square root of the pressure at the hydrant.

If, for instance, the case of a $1\frac{1}{4}$ inch nozzle on 300 feet of best hose is taken, and first, correcting the hydrant pressure for any difference in elevation which there may be between the gauge at the hydrant and the point of discharge, we see that, with a hydrant pressure of 65 pounds, 234 gallons per minute is discharged, while to discharge 468 gallons per minute, or double the above quantity, a hydrant pressure of four times as great will be required.

Or take a room full of automatic sprinklers, and first allowing in each case for any fixed difference in elevation between the pressure gauge and the level of the discharging orifices, we find that the same system of sprinklers which discharges 1,000 gallons per minute, with a pressure of 80 pounds per square inch, will discharge 500 gallons per minute with a pressure of 20 pounds.

Referring again to Fig. 6, take at random any reasonable flow and compute the friction loss in A B C D. If we use Weston's tables, based on Darcy, (and the writer regards them as the most convenient tables which have ever yet been published) but translate pressures into pounds per square inch and add 50 per cent. to Weston's values, which are for smooth straight pipe, to allow for crooks and moderate corrosion, we find the loss from

A to B in 500 ft. of 8 in. pipe carrying 500 gal. p. m.........= 1.80
B to D in 1500 " 6 " " " " " ....=22.63

Total loss along A B C D........................=24.43

On a piece of cross section paper and upon any convenient scale plot the point Q with distances 24.43 lbs. and 500 gal. Assuming other rates of flow and computing the friction loss in each we plot other points and through them draw the curve A B C D. (Or more easily we may get the points for this curve by making it a curve of squares and saying that at half the first number of gallons the loss will be ¼ as great. At ⅓ will be 1-9 as great, etc.)

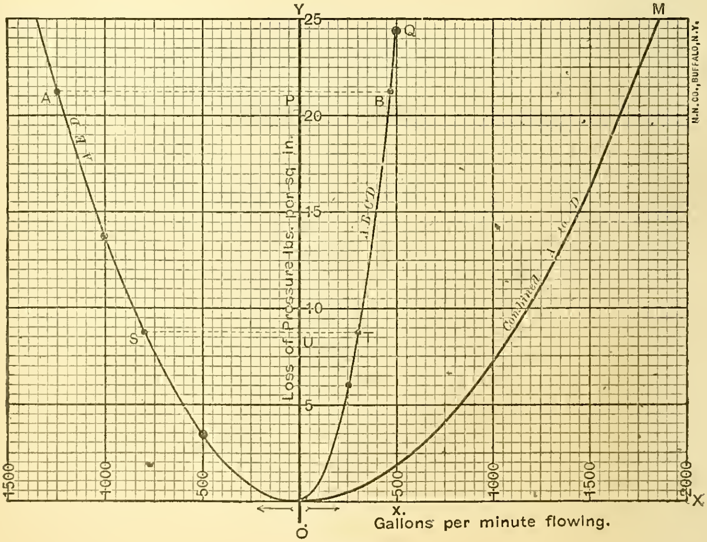

Fig. 7.

Next construct a similar curve for the loss along A E D. It is best to plot this with the same ordinates but with abscissas measured off in the opposite

direction. The loss in A E D, 1,000 feet of 8-inch pipe, 500 gallons, is 3.56 pounds, and for 1,000 gallons is 14.24 pounds ; thus a curve, O S A, is quickly constructed.

Now the condition is that the loss of pressure from A to D, around by the circuit, A B C D, is equal to the loss in A E D, and for any given loss of head, as P=21.25 pounds—the delivery of the pipe, A B C D, will be represented by P B, while the delivery of A E D will be represented by the abscissa, P A. Conversely, if we have any given quantity, as 1,100 gallons per minute, and mark off a distance proportional to it by the scale of the new abscissas on the edge of a strip of paper, and then slide this strip of paper up along the plotting, keeping its edge parallel to the axis of O X, until the two marks coincide with points on the two curves, as S T, it is obvious that O Y will represent the loss of head, and that the distances, U S and U T, will give the respective quantities flowing in each of the two pipes.

For use in further computations, it may be well to plot a new curve, O M, with ordinates the same as for the two curves just described, but whose abscissas are the sums of those for the other curves.

This new curve can be constructed in a minute or two by merely taking off the abscissas from the two other curves on the edge of a strip of paper, and then sliding this along on the level of the same ordinate.

Next, to get the loss of pressure between the source, M, and the discharge, N, it is the very simple problem of the loss from M to A plus the loss from A to D, determined as just described, plus the loss from D to N. Assume any reasonable number of gallons at random, say 1,000. Then the loss from M to A, 3,000 feet 12-inch pipe, 1,000 gallons, is 5.27 pounds ; from A to D by the curve, A D, in Fig. 5, 7.37 pounds ; from D to N, 1,000 feet 6-inch pipe, 1,000 gallons, 60.36 pounds ; or the total loss is 73 pounds. This is plotted on cross-section paper, and a curve of squares drawn through the point, giving a diagram, Fig. 8, from which the loss from M to N can be determined under any rate of flow.

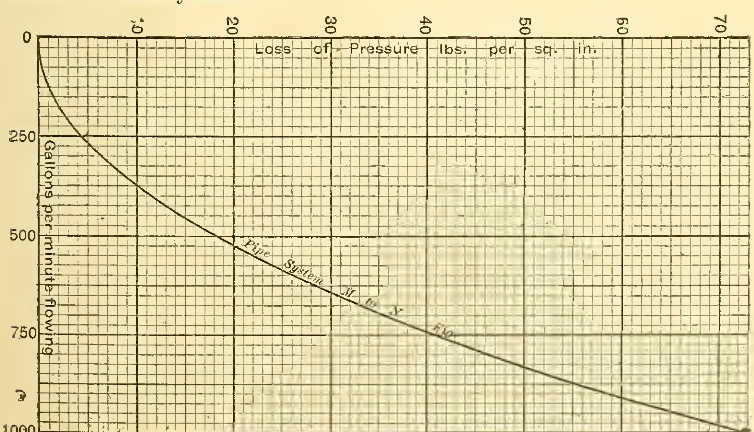

FIG. 8.

Case II.—Next take the more complicated arrangement shown in Fig. 9.

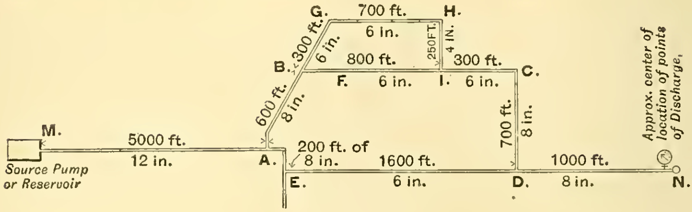

Fig. 9.

Here the loss from B to I must first be computed on the basis of some assumed quantity, say 500 gallons per minute, by the methods already outlined. In this manner we obtain the curves B F I and B G H I of Fig. 10. Thus, loss in B G H, 1,000 feet of 6-inch pipe, with 500 gallons per minute, will be 15.07 pounds.

H I, 250 feet 4-inch pipe, 500 gallons, will be 30.72 pounds ; total loss in circuit B G H I, 45.79 pounds.

For B F I, 800 feet of 6-inch pipe, 500 gallons, loss will be 12 06 pounds.

Plotting the point in each curve thus found, we pass a curve of squares through each and obtain the two curves shown in the cut, and by combining these we get the full curve B to I.

Next assume at random some reasonable quantity as 750 gallons per minute, and compute the loss in A B and I C D. For A B this amounts to 4.63 pounds, for I C to 10.18 pounds, and for C D to 5.44 pounds, or a total of 20.25 pounds. Adding to this the loss for this same quantity shown on the combined curve B I, which for 750 gallons is 11.6 pounds, we have 11.6 + 20.25=31.85 pounds, as the total loss when 750 gallons flows from A around B and C to D, and passing a curve of squares through this point we have the curve A G F C D. Next we compute the loss in A E D, with some random quantity, say 500 gallons. For A E this is 0.69 pounds, for E D it is 24.14 pounds, or a total of 24.83 pounds. Now, by our curve A G F C D, etc., we see that when a difference of 24.83 pounds exists between the pressures at A and D, 656 gallons per minute will flow around B and C, which, added to the 500 gallons flowing around E, give 1,156 gallons that the combination of three pipes will conduct from A to D under a difference of pressure of 24.83 pounds.

Now to find the total from M to N, we may as a starting point for the curve assume a new quantity at random, or take the 1,156 gallons just used. We see by the tables that with 1,156 gallons the loss in 5,000 feet of 12-inch pipe will be 11.72 pounds, and in 1,000 feet of 8-inch pipe it will be 18.42 pounds, or a total of 30.12 pounds, which, plus the loss from A to D, 24.83 pounds makes a grand total of 54.95 pounds. Passing a line of squares through this point we obtain the curve M to N.

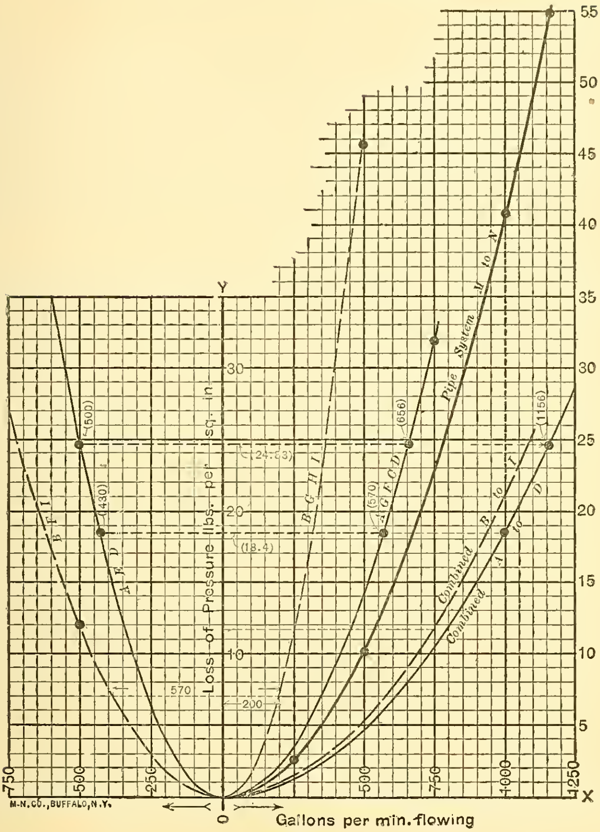

Fig 10.

From the various curves of Fig. 10, we can instantly answer all questions as to how much the static pressure from a reservoir at M, Fig. 9, will be lessened under any given draught at N. Thus we see that with one 250-gallon stream flowing at P, it will be pulled down 2.5 pounds, with two streams 10 pounds, with four streams 41 pounds, and with six streams 91 pounds. Or we find that under a static reservoir pressure of 100 pounds at N, not more than two good fire streams can be drawn at N, for hose alone, or not more than six streams with a steamer drawing from the pipes. Or we see that, with a pump at M, 80 + 41 or 121 pounds pressure, would be required to force water enough for four fire streams through the pipe system and still have a first-class pressure of 80 pounds at the hydrant. Again, we can see from the diagram that, with 1,000 gallons being drawn at N, while the total loss is 41 pounds, the loss from A to D is but 18.4 pounds, and that of this 1,000 gallons

430 gallons flows by E, while the remaining 570 gallons flows by B. We see by marking this off on the edge of a strip of paper and sliding it so its ends coincide with the curves B F I and B G H I, that only 200 gallons of the water will come by way of G H.

The diagram thus serves very conveniently to answer almost instantly any question regarding the proportion of the flow which each pipe in the system carries or the loss due to friction within any part of the system.

It will be found in practice that the problem is often less simple than that just solved, by reason of variations in elevations of the ground or the greater complications in the cross connections of the pipes.

Allowance is easily made for differences of elevation, but the problem of the subdivision of the flow may readily be so indeterminate that an exact solution is not worth attempting.

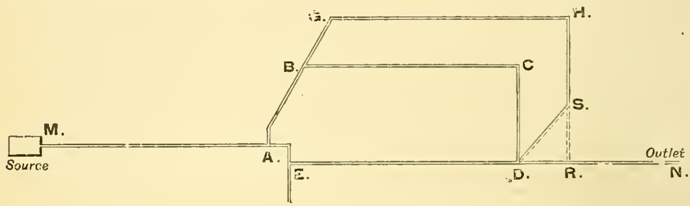

Fig. 11.

If in Fig. 9 the pipe G H had returned into a pipe other than that from which it branched off at B, and had, for instance, returned into the pipe D N, at R, as in Fig. 11, the problem could not be solved by the comparatively simple method just outlined, and the mathematical relation concerning the subdivision of the flow in the three different channels would appear almost hopelessly complicated.

Often, however, it may give a convenient solution, to ignore temporarily a pipe like B C D, or whichever pipe may be least efficient for the supply in question, and see what the loss of head in the other two would be. By such approximations and an exercise of judgment one can get at the state of things with an error inside of five pounds, which often may be near enough.

When the pipe which "short-circuits" the loop has its ends at proportionally the same distance down on the hydraulic grade between A and R, then since the pressure would be the same at both its ends, no flow would take place through it, and it could be ignored as just suggested, without error.

In the more complicated common practical case, a man whose judgment has been trained by a study of hydraulic problems, can often ignore certain of the cross connections and make certain assumed rearrangements all on the safe side, as for instance, in Fig. 11, it could be assumed that B G H returned into the main line at D instead of R, in which case the problem is readily solved; or taking the network of pipes certain main lines of delivery toward the joint in question can be mapped out and the other pipes either neglected or included in a lump allowance, such that the whole computation will be on the safe side.

Any little niceties of computation would be far out-weighed by possible differences in conducting power or by differences in the formulas of different authorities.

Thus far we have treated the problem as though the ground were level. In the question of how much the pressure at a given point will be reduced under a given draught, the elevation of the pipes enters only indirectly and to allow for differences of elevation in a hilly town after having computed our hydraulic grades is so simple a problem as to require no special mention.

DISCUSSION.

Mr. Brackett. In connection with Mr. Freeman's paper, which is certainly a very valuable and instructive one, some facts which show the present status of the distribution system in some of the larger cities of the country, and how far many of the present systems fall short of what he has shown us they ought to be, may be of interest. To begin with the question of the size of pipe, although it seems to be decided that 3 and 4-inch pipe should not be used for distribution, it is nevertheless a fact that some of the larger cities, and I might cite Baltimore as a shining example, use a very large proportion of small pipe and are adding it in large quantities year after year. The tables on page 78 give the mileage of the different sizes of pipe in the larger cities of the country and the percentages of the different sizes

Baltimore has about 250 miles or 56 per cent. of its mileage less than 6 inches in diameter. The percentage of 12-inch pipe in the different cities is as follows: New York, 24.6; Chicago, 6.5; St. Louis, 11; Boston, 28.6. Boston has the largest percentage of 12-inch pipe of any of the large cities of the country.

In considering the question of hydrants, there is not only to be considered the distance apart at which the hydrants should be placed, but also the size and number of outlets or steamer connections which are provided with the hydrants. In some of the cities hydrants are used that have only one 2½-inch connection. In New York all the hydrants which were put in during the last year have simply one 2½-inch connection. They have to-day about 6800 hydrants of that pattern out of 8700, and the barrel of the hydrant is, I think, 3½ inches in diameter. In Brooklyn all of the hydrants have one 2½-inch hose connection, while in Boston the post hydrants have two 2½-inch and one 4-inch outlet. The Lowry hydrants used in Boston have a 9-inch barrel and are set in the centre of the street. They have four steamer connections, two 4-inch and two 2½. By using hydrants to which four steamers can be connected, the fire department is enabled to mass the steamers. As Mr. Freeman has stated, at the Thanksgiving fire 52 steamers were placed within 600 feet of the fire, and they might have all been placed within 500 feet if it had been desirable

For the purpose of comparison, a study has been made of the distribution systems of some of the large cities of the country with a view of showing how many steamers could be massed within 500 feet of given points. A distance of 500 feet would give in practice many lines of hose not

MILES OF PIPE IN USE IN DIFFERENT CITIES.

	3″	4″	4½″	6″	8″	10″	12″	14″	15″	16″	18″	20″	24″	30″	36″	40″	42″	46″	48″	Total.
New York,		6.2		422.6		1.2	168.4			3.2		37.9	2.2	7.9	21.6				14.3	685.5
Chicago,	3.2	203.9		580.8	242.1	5.1	78.9	3.3		36.8		1.7	33.9	1.0	14.3				0.3	1205.3
Philadelphia,																				1001.6
Brooklyn,		0.7		286.3	77.9		35.9			2.1		19.7		6.4	8.9				12 1	450.0
St. Louis,	11.9	1.9		239.1	10.5	9.8	40.9		10.2			25.8		7.1	10.6				0.2	368.0
Boston,		24.0		216.0	59.5	8.3	147.0			13.2		11.3	11.0	10.9	4.0	4.4			4.8	514 4
Baltimore,	108.7	126.6	13.8	64.2	6.3	35.8	11.7			7.2	1.2	22.1		10.5	5.3	7.4				420.7
Cincinnati,	11.1	91.7		85.9	12.6	45.6	3.9			6.3		17.9	1.2	0.1	4.8	0 7		0.7	0.1	282.6
Cleveland,	2.7	23.9		187.4	58.0	21.6	5.7			5.4		3.3	2.9	14.5	7.9					333.3
Pittsburg,		52.		95.6	23.4	6.0	10.6	0.3	7.0	1.0		8.0	1.8	5.2	6.3				0.7	217.9
Washington,	5.5	24.		142.0	1.1	2.3	14.5					3.8	0.5	6.2	4.3				5.6	209.8
Detroit.	15.9	150.3		135.1	35.8	18.3	0.7			4 9		0.1	13.9	9.3	0.1		8.5			392.9

PERCENTAGES OF DIFFERENT SIZES OF PIPE USED IN DIFFERENT CITIES.

	3	4	4½	6	8	10	12	14	15	16	18	20	24	30	36	40	42	46	48	Percent'ge less than 8 inches	Percent'ge less than 6 inches
New York,		0.9		61.6		0.2	24.6			0.5		5.5	0.3	1.2	3.1				2.1	62.5	0 9
Chicago,	0.3	16.9		48.2	20.1	0.4	6.5	0.3		3.1		0.1	2.8	0.1	1.2					65.4	17.2
Philadelphia,																					
Brooklyn,		0.2		63.6	17.3		8.0			0.4		4.4		1.4	2.0				2.7	63.8	0.2
St. Louis,	3.2	0.5		65.0	2.9	2.7	11.1		2.8			7.0		1.9	2 9					68.7	3.7
Boston,		4.7		42.0	11.6	1.6	28.6			2.6		2.2	2.1	2.1	0.8	0.8			0.9	46.7	4.7
Baltimore,	25.8	30.1	3.3	15.3	1.5	8.5	2.8			1.7	0.3	5.2		2 5	1.2	1.8				74.5	55.9
Cincinnati,	3.9	32.4		30.4	4.5	16.1	1.4			2.2		6.3	0.4	0.1	1 7	0.2		.02	0.1	66.7	36.3
Cleveland,	0.8	7.2		56.2	17.4	6.5	1.7			1.6		1.0	0.9	4.3	2.4					64.2	8.0
Pittsburg,		23.9		43.9	10.8	2.7	4.8	0.1	3.2	0.5		3.7	0.8	2.4	2.9				0.3	67.8	23.9
Washington,	2.6	11.4		67.7	0.5	1.1	6.9					1.8	0.2	3.0	2.1				2.7	81.7	14.0
Detroit.	4.0	38.3		34.4	9.1	4.7	0.2			1.2			3 5	2.4			2 2			76.7	42.3

exceeding 300 feet, because a fire of any magnitude would cover area enough so the lines of hose would be shorter. These distances are all measured from one centre. In the city of Brooklyn, for example, more than 15 steamers or 30 streams cannot be concentrated within 500 feet of any point in the city. I have selected 14 points, all in or near the business portion of different cities, and investigation shows that the number of steamers which would receive an adequate supply, that is, a supply of 500 gallons for each steamer, or two streams, varies from 60 down to 5. The figures for the different cities are as follows: New York, from 10 to 60; Chicago, 13 to 35; Philadelphia, 7 to 23; Brooklyn, 5 to 15; St. Louis, 4 to 19; Boston, 25 to 60; Baltimore, from 3 to 37; Detroit, from 5 to 43. In most of the cities the hydrants are placed farther apart than 300 feet. Hydrants in the business portion of any city should not be placed more than from 150 to 200 feet apart.

Mr. Freeman advocates the use of post hydrants in preference to the Lowry pattern, and for a city or town having wide side-walks or where the hydrants cannot have constant supervision, I do not differ from his opinion, but for narrow streets and side-walks in a large city, the Lowry hydrant is preferable.

The post hydrant is a more dangerous obstruction to pedestrians than lamp posts or telegraph poles on account of their height. A person can hardly fall over a telegraph post although he may run against it.

The post hydrant is not easily accessible to more than two steamers while the Lowry will accommodate four, and in order to concentrate a given number of steamers within any area, twice as many post hydrants will be required as would be necessary if the Lowry were used

J. T. Fanning. A perusal of Mr. John H. Freeman's paper on the "Arrangement of Hydrants and Water Pipes for the Protection of a City Against Fire" convinces me that it is one of those rare papers that after the first careful reading may be profitably returned to for careful study in detail.

Mr. Freeman has taught us in the text and diagrams how he has reduced water supply mathematics to the plane of simple arithmetical rules and to rapid methods of reaching reliable data governing the proportions of a Fire Protection system. Since so large a share of the expense of public water supplies for towns and small cities, and for the suburbs of all cities is incurred to make them efficient fire checking systems the enumeration of essentials of a good system is timely.

Mr. Freeman emphasizes that there must be an ample quantity of water, six to twelve hose streams in the small cities, and increasing to thirty to fifty streams in cities of 200,000 population and 250 to 300 gallons of water per minute for each of these streams. He emphasizes also the desirability of having forty to fifty lbs. water pressure at the play pipe.

Consider in detail these two of the suggested essentials for the protection of a city, a mill or a warehouse against fire; viz: Ample quantity of water and ample pressure at the nozzles together with the emphasized fact that the fire supply largely decides the size of distribution mains.

Those who have to test public systems of water supply and report upon their efficiencies know how rarely these two essentials are found together in the same system. Those who plan new water supply systems for cities or manufacturing corporations know how confident committees are, or how easily they deceive themselves that if an ample quantity of water is supplied at the pump or reservoir ample pressure will somehow result in the streams from the nozzles. Too often when an emergency exists, it is found that ample quantity of both water and pressure at the source do not insure both at the nozzles. The reasons may be easily discovered.

When the pressure of the pumps or the elevation of the reservoir gives in a main a pressure equivalent to that of 200 feet head of water, the water has then within it a quality termed "Energy." It can do work to a certain computable amount, measured by the 200 feet head. That energy may be expended in the work of turning a loaded turbine motor, or in pushing a piston, pushing other water rapidly forward in the same main, or in pushing a jet of water into the air from a nozzle. If a part of its energy is expended in one kind of work as much less energy remains available for other work.

A pressure of 200 feet head in a main ordinarily impresses an inexperienced committeeman as ensuring all that is to be desired for a fire service of a small city, and if this main pipe is fourteen inches in diameter and only two miles in length from the pumping station to the center of business, he feels assurred that his city will have a fire protection that has never been excelled, and that his four million gallon pump will send at least ten splendid fire streams high upon the church spire.

A 1 $\frac{1}{8}$-inch hose stream, with force to reach 80 feet above the level of the nozzle discharges as Mr. Freeman has previously shown by experiment, about 280 gallons per minute, or at the rate of .4 million gallons per twenty-four hours. The ten streams will discharge at the rate of about four million gallons per twenty-four hours.

The work, which we call friction, of pushing four million gallons per day through a 14-inch diameter, smoothly coated pipe, consumes energy in each thousand feet length of the pipe equal to the amount of energy given by nine and one-third feet head, or approximately 50 feet friction head per mile, or 100 feet in two miles.

If each of the ten streams is from a 1 $\frac{1}{8}$-inch nozzle and rises 80 feet high then it must have about 56 pounds per square inch or 129 feet head pressure at the play pipe.

If the hose is 100 feet in length, $2\frac{1}{2}$ inches diameter and smoothly lined with rubber, the energy consumed in the hose will be approximately one-half foot per lineal foot of hose, or fifty feet in the one hundred feet length. We observe therefore that the supposed case will require the energy of 129 feet head to force the jet 80 feet high, 50 feet head to force 280 gallons per minute through 100 feet of hose and 100 feet head to force the four million gallon rate of flow for ten streams through two miles of

14-inch pipe ; that is, the pressure must be equal to 279 feet instead of 200 feet head at the pumps to give the anticipated splendid display or effective fire service of the ten streams.

In the above case, if the main was 16-inch diameter its friction loss of energy would be 50 feet; if 18-inch diameter, 27 5-10 feet; if 20-inch diameter 16 feet, instead of 100 feet when the main was 14-inch diameter. These illustrate that energies consumed in forcing water through a main or hose are lost as respects fire service, and will not again act in forcing water through a nozzle into the air.

If in the above case the anticipated result had been more modest, say six good fire streams at one mile distance from source of power, then the flow in the main for the streams alone would be at a rate of 2 4-10 million gallons, and its friction loss of pressure in the 14-inch main 18 5-10 feet, hose loss 50 feet and jet energy 129 feet or a total of 197 5-10 feet, and the anticipated result would be assured.

The effects in losses of energy in the system are as readily computable when the flow in the main is for both domestic and fire service.

The inference naturally drawn from Mr. Freeman's paper is that the usual inefficiency of public water supplies for fire protection is not mischance, but on the other hand his experienced eye sees in each instance both in accord with well known laws of nature and a faulty plan of pipe system, and he could sum up the series of expenditure of energy in hose, hydrant, branch, valve and main as he would add a column of ledger figures, and show where energy was wrongly expended that should have been saved to give force to the hose jets.

A further inference is that if the water supply system of a mill, a village or a great city is intelligently planned and built an efficient fire controlling system will certainly be assured.

THE FRANKLIN, N. H. WATER WORKS.

BY

F. L. FULLER, C. E., Boston.

The town of Franklin is situated on the Concord division of the Boston & Maine R. R. nineteen miles north of Concord and ninety-four from Boston. The population is about 4,000, of which 3,000 are within the villages of Franklin and Franklin Falls.

One of the great advantages of the town is its magnificent water power, mostly upon the Winnipiseogee river, which passes directly through the village of Franklin Falls.

This power is used by the numerous wood pulp and paper mills of the Winnipiseogee Paper Co. and by several large woolen and hosiery mills. The Winnipiseogee falls 132 feet within the limits of the town, improved by eight dams within a distance of one and one-half miles.

The owners of this power are entitled to 250 cubic feet per second, which amounts to a little over 3,700 horse power. The actual flow of the stream is, however, about twice this, and there is now in use about 7 500 horse power. On the stream flowing from Webster lake there is about 200 unimproved horse power, and on the Pemigewasset, which unites with the Winnipiseogee at a point between the two villages, forming the Merrimack, there is about 1,500 unimproved horse power.

Twelve miles above Franklin is lake Winnipiseogee, which has an area of about 72 square miles. Its outlet is the Winnipiseogee river, before referred to. This lake forms an immense reservoir, and as the flow from it is controlled by the mill owners below, the volume of water in the river is very constant and even in the driest season, when other streams are very low, this river has its usual amount of water, or nearly that.

For this reason the water privileges are very valuable. As a large amount of the power is used in making wood pulp, but comparatively few operatives are employed. If all the power were used in producing cotton or woolen goods, the population of the town would be many times greater.

Water Works were built by the town during the season of 1891, and consist of eight miles of cast iron pipe from 12 to 4 inches in diameter, a pumping plant operated by water power, and a covered masonry reservoir of half a million gallons capacity.

The work was done by contract and in a very satisfactory manner. The town bought all material except that used in the reservoir construction.

Cast iron pipe was furnished by the McNeal Pipe & Foundry Co., hydrants and gates by the Ludlow Valve Manufacturing Co , power pump by the Deane Steam Pump Co., and water wheel by the Holyoke Machine Co.

There are at present 160 services, and the consumption of water is about 80,000 gallons per day.

The pipe was laid by Messrs. Moore & Co., of Boston, Mr E. H. Gowing, member of this association, being one of the firm.

reservoir was built by Mr. John H. Fuller of Lowell.

The contracts were let during the winter of 1891, and pipe laying began April 20th, and was completed September 15th.

Excavation for the reservoir began on May 12th, and the work was completed October 15th.

The masonry was therefore not exposed to freezing weather.

THE PIPE SYSTEM.

This is shown on the accompanying map of the town and by a copy of the final estimate for pipe laying. The price for each item of work is also given:

Conduit pipe (laid on top of 10 in. pipe) Central St.	455.3		
" " " " " " " " " Force Main,	171.9	627.2	
" " " " side " " " " Force Main,	239.0		
Laying 1650.0 lineal feet of 12 inch cast iron pipe at	$0.29		$478.50
" 494.2 " " " 12 " " " " "	0.40		197.68
" 3866.3 " " " 10 " " " " "	0.239		924.05
" 9099.1 " " " 8 " " " " "	0.239		2174.68
" 20147.9 " " " 6 " " " " "	0.239		4815.35
" 239.0 " " " 6 " conduit " "	0.239		57.12
" 627.2 " " " 6 " " " "	0.169		106.00
" 1696.5 " " " 4 " cast iron " "	0.239		405.46
320.27 cubic yards rock excavation	3.50		1120.95
666.99 " " extra earth excavation	0.75		500.24
			$10780.03
Amount allowed for extra work			129.53
			$10,909.56

As will be seen from this table only five per cent. of this pipe is 4 inch. Six per cent is 12 inch. Ten per cent. is 10 inch. Twenty-five per cent. is 8 inch and fifty-four per cent. is 6 inch.

The weight of pipe was varied to conform to the pressure. The greatest static pressure on the 12-inch pipe which is nearest the reservoir is 51 lbs. There was but one weight of this pipe, viz., 70 lbs. per foot.

There are three weights or classes of 10-inch, 55, 60 and 65 lbs. per foot.

The greatest pressure on the 10-inch pipe is 122 lbs.

There are four weights of 8-inch pipe. Class A 41 lbs. per foot. Class B 43 lbs. per foot. Class C 45 lbs. per foot, and Class D 47 lbs. per foot.

The greatest pressure on the 8-inch pipe is 118 lbs.

There are four weights of 6-inch pipe, viz., 26, 28, 30 and 32 lbs. per foot. The former is used as a conduit pipe for conveying water from springs to the pump well at the pumping station and is under but little pressure. The greatest pressure on the 6-inch pipe is 122 lbs.

The 4-inch pipe weighed 18 and 19 lbs. per foot. The greatest pressure upon it is 101 lbs. It required a great deal of care to get the proper class of pipe in the right location but the saving to the town by the grading of the pipe was very considerable.

If the different sizes had been of one weight and that the heaviest, it would have required 42½ tons of additional iron at an increased cost of $915. The

pipe is much lighter than that laid in many towns and cities, nevertheless there have been but three leaks, only two of which were due to cracked pipe. These were on the 12-inch line near the reservoir, where the pressure was small. These pipes were probably cracked in transportation and the defect overlooked at the time of laying.

The question might be raised here whether a good deal of money has not been unnecessarily spent for excessively heavy pipe. A 10-inch pipe laid in Marblehead about a dozen years ago, to convey water from a small pond for hydrant use, in case of fire, weighs 80 lbs. per foot and at the time it was put in was under a pressure of only about 15 lbs. per square inch. In the new system in the same town, the same size of pipe weighs 63 lbs. per foot and is under a pressure of 60 to 70 lbs.

But few pipes are ever broken by direct water pressure, and the interest on the money saved will repair many leaks, or the money saved can with advantage be put into extra hydrants or larger pipe.

There are three river crossings. In two cases the 10-inch pipe rests on wooden cribs filled with stone, and in the third case an 8-inch pipe supplying the village of Franklin is carried over the Pemigewasset river on the floor of a covered wooden bridge.

It was desired to carry this pipe on the river bottom but the bed is full of large boulders and as the water is not very deep, it was feared that the pipe would be broken by the logs and floating ice in the spring of the year. The bottom of the river is at a considerable depth below the bridge, and the banks are very abrupt, and not favorable to the laying of pipe.

It was therefore decided to lay the pipe on the bridge, although subject to much vibration, where a leak would be much more easily discovered than if the pipe were under water.

The bridge is of three spans of about 120 feet each, and no restriction is placed on the speed at which teams are driven through the bridge. As a result, there is much fast driving, and as it is between the larger village of the town and the principal railroad station, many teams of all kinds pass through it. There are four 8-inch one eight bends used in getting from the bottom of the ditch to the bridge floor. At first these bends, two at each end of the bridge, were not strapped together and one of the bends at the west end of the bridge was forced from the pipe with which it was connected, and a bad washout might have resulted, had it not been detected at once and water shut off.

The bends at both ends were at once securely connected with wrought iron bands and bolts, and no further trouble has been had.

The result of the vibration is felt most at the ends of the bridge where the pipe enters the ground, and is therefore ridgidly fixed. The up and down motion of the pipe on the bridge tends to work the pipe out of the joints of the fixed or rigid pipe.

The pipe should be supported on trusses resting on the piers and be entirely independent of the bridge floor. The pipe is in a measure prevented from freezing by a double boxing with an air space between. There was no

FRANKLIN N.H. WATER WORKS.
PLAN SHOWING LOCATION OF
PIPES, GATES, HYDRANTS, &c.
MAR. 1891.
SCALE OF FEET
500
1000
F.L. FULLER.
CIVIL ENGINEER
12 PEARL ST. BOSTON.
HYDRANTS SHOWN THUS
GATES " "
BRANCHES FOR EXTENSION
67 HYDRANTS
COVERED MASONRY
RESERVOIR
Capacity 504,300 gallons.
SPRINGS
PARTIAL SOURCE
OF SUPPLY
PUMPING
STATION
PEMIGEWASSETT
RIVER
WINNIPISEOGEE
RIVER
MERRIMACK
RIVER
BOSTON
AND
MAINE
RAILROAD
BRISTOL BRANCH
R.R.
WEBSTER ST.
MAIN
WATER ST.
DEPOT ST.
ANDERSON AVE.
CENTRAL
BOW
WINNIPISEOGEE
ST.
NEW HAMPTON
ROAD
SMITH
CHURCH
ST.
SCHOOL ST.
HIGH
ELKINS
FRANKLIN
RIVER
PLEASANT
OAK ST.
CHESTNUT ST.
PINE ST.
WALNUT ST.
CRESCENT AV.
PROSPECT
HIGHLAND AVE.
ELM AVE.
TILTON
SPRING
NESMITH ST.
TILTON ROAD
HILL ROAD
PARK
SANBORN
PEARL ST.
MAPLE
TO TILTON
NEEDLE FACTORY
JOS. BROWN
AIKEN'S HOSIERY MILL
STEVENS' MILL
YOUNG'S HOTEL
BANK
HIGH SCHOOL
BAP. CH.
UNIT. CH.
CONG. CH.
CHAPEL
CH. BAR CH.
P.O.
DEPOT
W.P. CO.
ENGINE HOUSE
W.F. DANIELL
W.F. DANIELL'S FARM
WALTER AIKEN
PULP MILL
H. DANIELL'S PULP MILL
SULPHITE SPRING
4" PIPE RUNS BY GRAVITY TO PUMPING STA.
4" PIPE RUNS BY GRAVITY TO PUMPING STATION
6" plugged for future hydrant
C.C. KENRICK
RUSSELL ST.
VIEW ST.
RAIL ROAD AVE.

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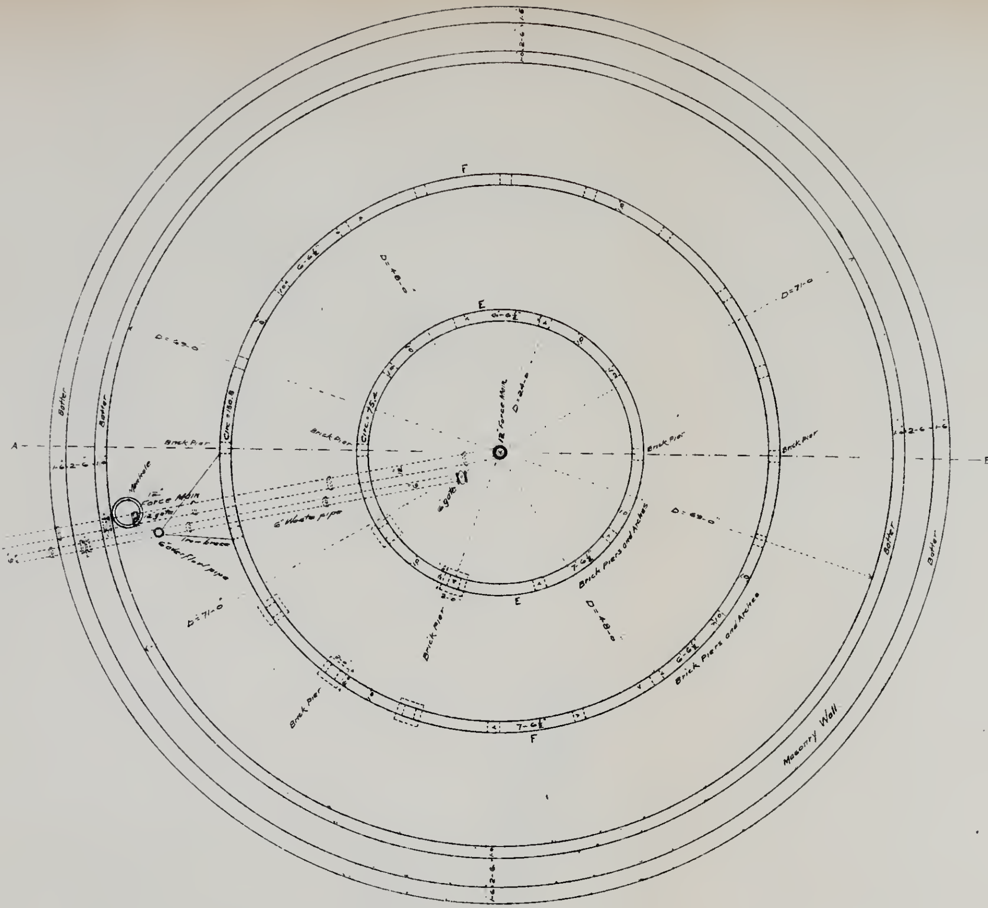
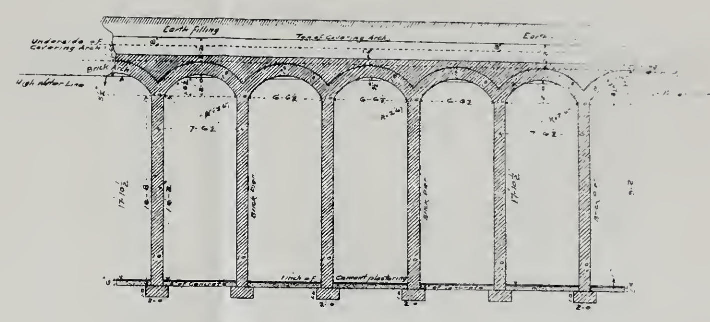


HORIZONTAL SECTION ON C-D



SECTION OF OUTER RING OF PIERS AND SUPPORTING ARCHES F-F

The Inner Ring of piers is the same except the piers are 2 in. longer.

FRANKLIN N.H. WATER WORKS.

PLAN SHOWING COVERED MASONRY RESERVOIR.

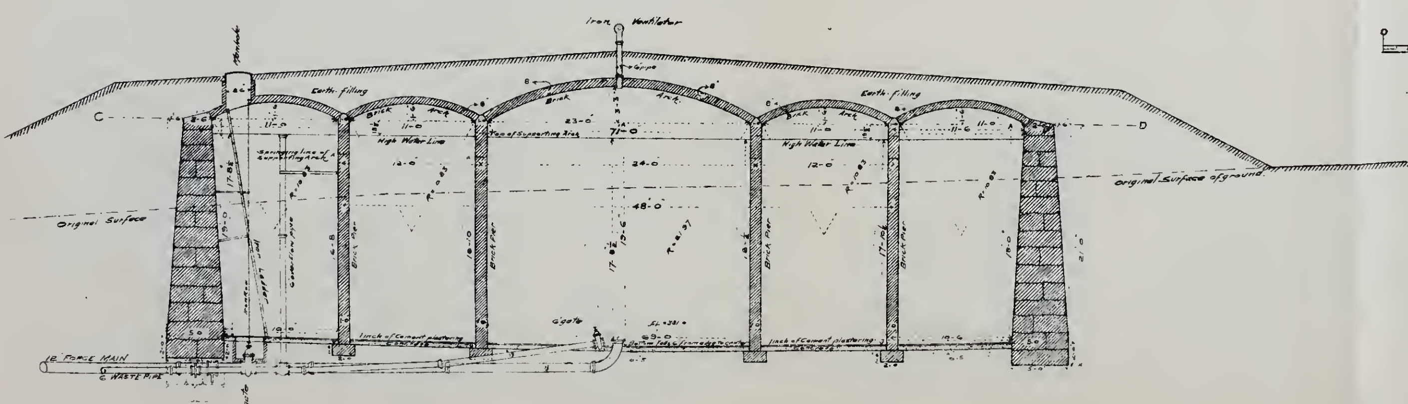
JAN. 12. 1892

SCALE OF FEET

0 5 10 15 20

F.L. FULLER, CIVIL ENGINEER.
No 12 Pearl St. Boston

Capacity to High Water Line = 504,300 gallons.



SECTIONAL VIEW

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trouble last winter on account of ice. The water used in the village of Franklin would naturally cause circulation enough, except at night to prevent freezing.

A small supply at night to a railroad tank, keeps up this necessary circulation.

GATES.

There is	1	12 inch gate,	or one to	2,144 feet
" are	13	10 " gates	" " "	297 "
" "	19	8 " "	" " "	478 "
" "	40	6 " "	" " "	504 "
" "	8	4 " "	" " "	212 "
Total	81			

HYDRANTS.

There are 67 hydrants; of these 11 in the highest part of the town have steamer nozzles and five inch seat rings. Fifty-five are of the same size, but have no steamer nozzles.

All the above have 6-inch branches or connections. Only one hydraut has a 4-inch branch. The writer believes that all hydrants should have 6-inch branches, and at least a $4\frac{1}{2}$ inch inlet or seat ring if it is a gate hydrant.

As the town is located on land sloping to the rivers, there is great difference in elevation and consequently in pressure. The average pressure for the sixty-seven hydrants is 92 lbs. per square inch, which is much larger than in most towns.

RESERVOIR.

This is located about 4,000 feet from the centre of the village of Franklin Falls and about 250 feet above its principal street. It is circular in form and covered with 8-inch brick arches. Its average diameter is 70 feet and contains when full 17 feet $8\frac{1}{2}$ inches of water, or 504,300 gallons. It is partly in excavation and partly in embankment, the earth excavation being just enough to form the embankment.

The material is a clayey hardpan and well calculated to form a solid and compact bank around the outside of the masonry wall. This wall is 5 feet thick at the bottom, $2\frac{1}{2}$ feet thick at the top and 21 feet high. It is built of rubble masonry made of split field boulders and Rosendale cement. The wall has a batter of one foot on the inside, and one foot six inches on the outside.

The top of the wall was left in the form of a skew-back from which to start the covering arch. After the masonry wall was completed, two circular rows of brick piers one foot square were built to a height of about 17 feet. The inner row is on a circle whose diameter is 24 feet. The piers are spaced 7.54 feet on centres. There are ten piers in this row.

The outer row consists of twenty piers, spaced the same distance on centers, on a circle 48 feet in diameter. When these piers were carried to the proper height they were connected with lintel arches 12 inches thick, the top of the arch being level with the top of the masonry wall. The spandrill filling is of brick and carried up to the crown of the lintel arch.

These two brick rings, carried by the brick piers, support the two brick covering arches and dome. The covering arches have a rise of 1.5 feet, a span of 11 feet, and a thickness of 8 inches. The dome covering the central portion, has a span of 23 feet and a rise of 3.25 feet. The thickness is also 8 inches.

Before the covering arches were started, the embankment was raised to the level of the top of the masonry wall to assist in withstanding the thrust of the arches. The bank was thoroughly puddled and rolled, making it compact and solid.

The covering arches and dome were built on accurately formed centers supported from the bottom of the reservoir. These centers were allowed to remain as long as possible before removal, but as a considerable number of masons were employed, and as in the case of covering arches, the same centers were used over and over again, they were generally removed on the third day, sometimes perhaps on the second. By having a larger number of centers they might have remained longer, but this would have caused considerable additional expense.

Careful watch was kept of the brick work on the removal of the centers, but no change of form was observed. The following copy of the final estimate shows the quantities of materials and prices paid.

Final estimate of work done by John H. Fuller in building a covered reservoir, under contract dated April 11, 1891.

2,882.4 cu. yds.	Earth excavation..	at $0.40	$1,152.96
714.8 "	Rubble masonry.	6.80	4,860.64
18.6 "	Portland cement brick work.........	16.96	315.46
220.8 "	American " " "	13.96	1,686.37
57.5 "	" " concrete	6.75	388.12
410.8 sq. yds.	Finishing coat on bottom............	0.45	184.68
464.4 "	Portland cement plaster coat on sides	0.40	185.76
52.5 lineal ft.	12 in. pipe laying	0.50	26.25
73.9 "	6 "	0.35	25.87
Extra on account of using Portland Cement on bottom, 40 bbls	....	1.80	72.00
2 bbls. Portland Cement used around pipes and gates		3.40	6.80
Extra, not included above	....		187.12
			$9,092.03

SERVICE PIPES.

These are of lead, and the ordinary size is one-half inch in diameter.

The spring water of the town which is similar to that furnished by the new system of water works, seems to have no effect upon lead pipe, hence it was adopted for service pipes. In the construction of the works many small lead pipes were accidentally cut.

These pipes invariably showed a brown coating on the inside and were well preserved.

This could not have been the case if the water dissolved much lead, as some of them have been in for many years. No cases of lead poisoning are known to have occurred.

For the lower levels where the pressure is about 100 lbs. per square inch, the pipe weighs, for $\frac{1}{2}$ inch, 2 lbs. per foot; for $\frac{5}{8}$ inch, 3 lbs. per foot; for $\frac{3}{4}$ inch, 4 lbs. per foot.

THE WATER SUPPLY.

There are at present two sources of supply, the Elkins or Cold Brook springs and the Sulphite Paper Mill spring. There are seven of the former, scattered over an area of perhaps an acre. The springs are walled in with brick-work, and were developed to form an aqueduct supply for a small part of the town. The difference in elevation of the highest and lowest of these springs is about 16 feet, and their average elevation is a little less than 24 feet above the floor of the pumping station.

The water from both sources is carried by gravity to the pump well at the pumping station.

It was not convenient to measure the flow of these springs, and their exact capacity is not known, but the supply is probably ample for some time to come. The quality is excellent and being stored in a covered reservoir will not be affected by vegetable growths.

PUMPING STATION.

This is a brick building 26x27 feet outside dimensions. It is located on the south-west side of Bow street, and is on the north-east bank of the Winnipiseogee river. Within the building is the pump well 22 feet 8 inches long by 6 feet 7 inches wide, and is 8 feet deep. Its capacity is 8,930 gallons. Just above the bottom of the well a 4-inch waste pipe is laid through the masonry wall. It is provided with a 4-inch gate so that the well can be drained into the river.

The building also contains the pumping plant.

PUMPING MACHINERY.

The pump, which is operated by water power, was furnished by the Deane Steam Pump Co., of Holyoke, Mass. It is of the duplex pattern and has the following dimensions: Diameter of water plungers $11\frac{1}{2}$ inches, length of stroke 10 inches. The suction and discharge pipes are both 10 inches in diameter. The water is forced through about 2,600 feet of 10-inch and about 2,150 feet of 12-inch pipe to an elevation of about 250 feet.

The displacement at each revolution is $17\frac{1}{2}$ gallons.

Power for operating the pump is furnished by a 21-inch "Hercules" turbine water wheel manufactured by the Holyoks Machine Co. of Holyoke. The gearing connecting the wheel and pump is so proportioned that when the wheel is running at the proper speed, the pump makes about sixteen revolutions per minute. When the town requires more water than at present, the gears will be changed so that with the same number of revolutions of the wheel, more revolutions of the pump will be obtained.

Water is furnished to the wheel through an iron penstock or feeder 560 feet in length, varying in diameter from $4\frac{1}{2}$ to 2 feet. This water is supplied under a head of about $18\frac{1}{2}$ feet, and can be used through the night as well as during the day.

The total cost of construction was about $60,000, and the cost of the aqueduct system bought by the town was $25,000, making the total cost of the works $85,000.

OBITUARY.

ROBERT M. GOW—Superintendent Water Works, Medford, Mass., died June 6th, 1892. Joined this Association at the time of its organization, June 21st, 1882.

Mr. Gow was one of the organizers of this Association, and during the ten years of its existence was always enthusiastic in doing his part to promote its work. By his decease, the city which he served has lost a faithful official and this Association has been deprived of a true friend, who will be greatly missed by all members.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. VII. December, 1892. No. 2.

This Association, as a Body, is not responsible for the statements or opinions of any of its members.

FALL EXCURSION,

SEPTEMBER 14th, 1892.

The Fall Excursion took place at Middleboro, Mass., on Wednesday, September 14th, and was one of the most delightful outings in the history of the Association. The members were received at the depot and driven through the principal streets of the town to the Town Hall where they were received by a delegation of ladies under the leadership of Mrs. J. E. Beals, each member being decorated with a boutonniere. After a collation was served the party visited the pumping station, where the machinery and all surroundings were found to be in excellent order. The party was then driven to Lake Assawampsett where a "shore dinner" was served, which was notable for its excellence. From the lake the party was transferred to the top of Shockley Hill where a fine outlook was obtained of the chain of Middleboro ponds which taken collectively form the largest body of fresh water in the state. After the return trip to the depot a vote of thanks was tendered to all the entertainers in Middleboro who had done so much for the enjoyment of the members of the Association.

This excursion serves as a practical illustration of what a small town can do in the way of entertainment. The programme was carried out by the entertainers with a life and vim which many a more pretentious affair has lacked, and the entire party was enthusiastic over the result. The following is the list of those who were present :

MEMBERS.

Solon M. Allis, Supt., Malden, Mass.; Richard W. Bagnell, Plymouth, Mass.; Lewis M. Bancroft, Chairman Water Commissioners, Reading, Mass.; Joseph E. Beals, Supt., Middleboro, Mass.; Nathan B. Bickford, Supt., W. W. O. C. R. R., Boston, Mass.; Dexter Brackett, Asst. Engineer, Boston, Mass.; George F. Chace, Supt., Taunton, Mass.; E. J. Chadbourne, Supt., Holbrook, Mass.; R. C. P. Coggeshall, Supt., New Bedford, Mass.; H. W. Conant, Supt., Gardner, Mass.; Lucas Cushing, Asst. Supt., Boston, Mass.; Francis W. Dean, Mechanical Engineer, Boston, Mass.; Frank L. Fuller,

Civil Engineer, Boston, Mass.; W. J. Goldthwait, Marblehead, Mass.; Frank E. Hall, Supt., Quincy, Mass.; E. A. W. Hammatt, Civil Engineer, Boston, Mass.; L. M. Hastings, City Engineer, Cambridge, Mass.; Ansel G. Hayes, Asst. Supt., Middleboro, Mass.; Horace G. Holden, Supt., Nashua, N. H.; David B. Kempton, Commissioner, New Bedford, Mass.; Patrick Kieran, Supt., Fall River, Mass.: Wilbur F. Learned, Asst. Engineer, Boston W. W., Watertown, Mass.; Eugene P. LeBaron, chairman, Middleboro, Mass.; James W. Morse, Supt. Natick, Mass.; Hiram Nevons, Supt. Cambridge, Mass.; Edward C. Nichols, Commissioner, Reading, Mass.; Charles E. Pierce, Supt., East Providence, R. I; Henry W. Rogers, Supt., Haverhill, Mass.; Daniel Russell, Everett, Mass.; Frederick P. Stearns, Chief Engineer State Board of Health, Boston, Mass.; D. N. Tower, Supt., Cohassett, Mass.; Horace B. Winship, Civil Engineer, Norwich, Conn.; George E. Winslow, Supt., Waltham, Mass.; C. J. Underwood, Jr., *The Engineering Record*, New York city; J. G. Lufkin, National Meter Co., New York city; F. E. Stevens, Peet Valve Co., Boston, Mass.; N. F. Ryder, Varnish, Middleboro, Mass.; J. B. K. Otis, Union Water Meter Co., Worcester, Mass.; J. G. Reaser, Walworth Mfg. Co., Boston, Mass.; H. T. Duke, R. D. Wood & Co., Philadelphia, Penn.; H. A. Gorham, the George Woodman Co., Boston, Mass.

GUESTS.

Mrs. L. M. Bancroft, Reading, Mass.; Mrs. J. E. Beales, Middleboro, Mass.; Mrs. N. D. Bickford, Boston, Mass.; Mrs. George F. Chace, Taunton, Mass.; Mrs. E. J. Chadbourne, Holbrook, Mass.; Mr. and Mrs. Dexter, Holbrook, Mass.; Mrs. F. L. Fuller, Boston, Mass.; Mrs. F. E. Hall, Quincy, Mass.; Henry Howard, New Bedford, Mass.; Mrs. D. B. Kempton, New Bedford, Mass.; H. L. Lincoln, Cambridge, Mass.; Mrs. H. W. Rogers, Haverhill, Mass.; Mrs. Daniel Russell, Everett, Mass; Mrs. D. N. Tower, Cohassett, Mass.; Miss Smith, Cohassett, Mass.; E. A. Stevens, Jr., Middleboro, Mass.; A. R. Turner, Jr., Middleboro, Mass.

LAYING A SIPHON UNDER BROOD CANAL, CAMBRIDGE.

BY

John L. Harrington, Foreman, Cambridge, Mass.

I have felt for sometime that many of the annual reports of our departments might be made more interesting and instructive if the Manager or Superintendent saw fit to incorporate into them some account of special work performed by him, as it is not the large but small things we are looking for. With this fact in mind, I make the following description of the laying of a so-called inverted siphon under Brood Canal in Cambridge.

After the disastrous fire which consumed the buildings of the Damon Safe works, an economical opportunity was afforded the city to extend First

street to Main street by taking a small piece of land and building a bridge.

So First street was laid out, and an opportunity given to connect the two easterly extremities of our water system, thereby establishing a much needed circulation ; and early in the present year, the Water Board decided to lay a 12 in. pipe, making this connection. It is in this line that the siphon was laid.

The plans were made by City Engineer L. M. Hastings, and contemplated the laying of the siphon under the bridge in place of at one side, for the better protection of the pipe, and in consideration of its cost.

I say inverted siphon, knowing as we all do that no such thing can be; "A siphon is the oldest device for transferring water or other liquids to a lower level over a barrier," and the moment we invert it, it ceases to be a siphon. But the expression being usual, as applied to such work, I so refer to it.

Brood Canal is an artificial channel leading west from Charles River near West Boston bridge. In it the tide rises and falls about 10 feet. On either side is a sea wall, the distance between being 114 feet. The soil is mud on top, with fine sand below.

The siphon is made up of 12-inch cast iron pipes, with the Ward flexible joint for the horizontal part, and the ordinary bell joint for the vertical parts, and stretches across under the canal, within 5 feet of the walls up and through them, the total weight being about nine tons. The pipes of the Ward pattern weighed 1400 lbs. each.

Generally speaking, the form is five sides of an eight sided figure, built that way to give it greater depth at the draw, and less depth at the walls, so as not to weaken them

Because of this form the flexible joint was used. Otherwise a coffer dam or staging would have been necessary, in either case, at an additional expense.

Preparatory to sinking the siphon a trench was scooped out across the canal, perhaps 20 feet in width and 9 feet below low water, at its greatest depth, this width being necessary, as it seemed best to work the dredger parallel with the sides of the canal, and in this position, the shovel swung at a radius to give that width.

This trench limited our working time to three hours before and after high tide ; otherwise the scows were liable to ground on the edge and topple in. We also found it advisable to work quickly, as the action of the water rapidly filled in the trench. A delay of two days, caused by a storm, made necessary the services of a diver, to hoe out the deposit, before the siphon would settle home.

The siphon was put together upon four scows, in two sections, as the time at our disposal made it impossible to do more than one section a day by daylight.

To lay the pipe over the end of a scow as is usual with the flexible joint where the length of pipe to be laid is considerable, and no danger of grounding and dumping the work overboard, is possible, was not practicable in our case.

February 29, two 60 feet scows were brought up and placed parallel within 2 feet ¦ of each other, and secured in that position.

These scows were of the common pattern and have but a narrow platform on either side, perhaps 2 feet in width, the centre being open to receive mud. Our work was all done on these two platforms and between them. As the weight on these edges tended to list the scows, other pipes were placed on the opposite sides and rolled in toward the centre, when the siphon was let go.

As soon as the horizontal pipes of one section were made up, it was towed out into the river, where it could float, without grounding, until called for. That part of the vertical ends, which were sunk with the horizontal parts, was made up without them.

March 1st the second section was towed out and the following day we intended bringing both sections in, placing them end to end across the canal, making up and dropping the whole into place, but a severe storm came on at this time, and for two days no work could be done. No damage was sustained, and on March 4th the siphon was brought in and with the use of seven derricks was dropped into position. This was just as the tide was turning, so as to give us time to correct any miscalculation, if occasion required. This part of the work was accomplished inside of three days, leaving out of consideration the stormy ones.

It was the work of two days more to extend the ends up and through the walls, and set gates, one on each side of the canal. We were now ready to test, after which the vertical ends were boxed up and filled in with hot coal tar and gravel.

To test we made a connection with the street main, but finding the pressure dropped off, indicating a leak, we subjected the siphon to air pressure and judging from the bubbles appearing on the surface of the water, we located the leaks (for there were two of them) at the joints where the smallest angles were made; one on each side of the canal near the ends. A diver hammered up the joints, as best he could under the circumstances, and we afterward secured a satisfactory test, though it was deemed wise to put a quantity of oat meal in the siphon and allow it time to soak well into the joints.

It may be inferred the joints were badly run or improperly driven. I personally saw the pipe laid in a straight line. Each joint run without packing of any kind, and no lead escaped from a joint into the pipe, showing the pipes were driven home, and all were properly hammered. I am unable to determine the cause of these leaks, provided we assume the flexible points used were perfect joints. Most of them evidently were.

It ought not to have been, because of any strain, for these joints are specially made to stand such.

Mr. Townsend, the contract diver, described a case where a line of 6-inch pipe was laid with a flexible joint. When the test was applied a leak of considerable consequence was discovered, and numerous ways of stopping it were tried. He finally succeeded by sinking an anchor on the beach, attaching a tackle to it from the end of the pipe, and taking up the slack in the joints.

The finished siphon cost $1,694 89. Following is a list of the items, which go to make up the cost:

	New England Dredging Co	$310.00
15,781	lbs. Flexible Joint Pipe at .03¼	512.88
26	ft. Cast Iron Pipe at $1.04	27.04
	Boxing	350.00
2	12-inch Elbows at $10.50	21.00
2	12-inch Sleeves at $6	12.00
2	12-inch Tees at $15.65	31.30
2	12-inch Gates at $42.41	84.82
2	Iron Boxes at $4.50	9.00
600	lbs. Lead at .05	30.00
20	lbs Packing at .13	2.60
66¾	Days' Labor at $2	133.50
	Foreman	20.00
7	Days' Teaming at $2	14 00
	Gravel	14.00
11	Barrels Tar	30.75
	Diver Townsend	92.00
		$1694.89

We now have the siphon laid and the pressure is on, and I desire to devote a few moments to an attempt to explain some of the details.

When the siphon was dropped, the vertical ends stood but a few inches above the surface of the water at low tide. As the siphon was dropped at high tide, these ends were not visible, and it was necessary they should stand plumb. To accomplish this we drove a 12-inch wooden plug, one in each end, and into these plugs set a piece of 4-inch joist, long enough to show several feet above the water. By observing these sticks, we regulated the position of things below.

When the siphon was building, it lay between the scows, so the load came on the edges nearest together. When it was raised a few inches that the ropes and planks might be removed. long enough to allow it to drop below the platforms, the tendency was to separate the scows and spread the legs of the derricks. To overcome this, an iron rod was used, bent at both ends, so as to hook around the derrick legs, just over the pipe, one rod to each derrick. Before the siphon was dropped to the bottom, the ropes and planks were replaced, making all secure again. These rods were afterward returned to the blacksmith, and only the labor on them charged.

How to remove the tackles in 19 feet of water and not cut the ropes was the next question. It was done with the use of iron rings, placed around the pipe, one ring for each tackle, and they were left on the pipe.

These rings were of 1-inch round iron, 16 inches in diameter, and to each was attached a strong cord, long enough to reach to the surface of the water after the pipe was sunk, and it was fastened to a wooden float. This cord served to lift the rings clear of the top of the pipe, giving two inches of space, so as to get a hook under it, if occasion required after the siphon was sunk.

To connect these rings with the tackle block hooks, a special hook was made.

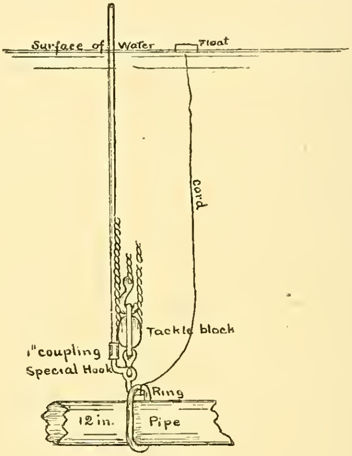
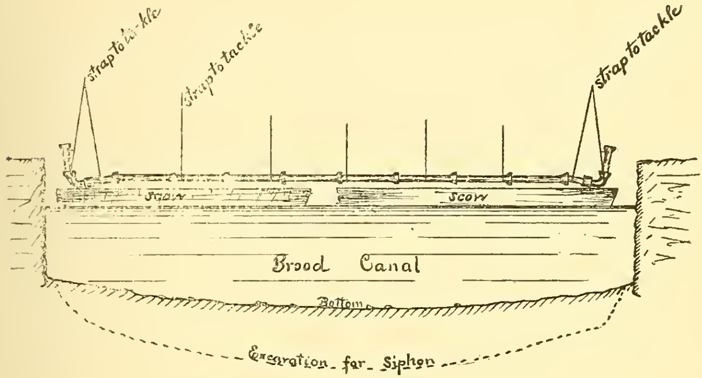


Fig. 1.

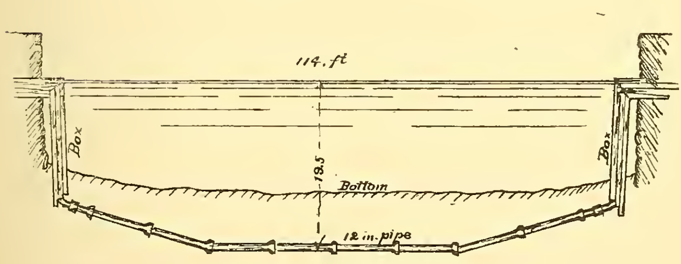
To get an idea of what it was like take two pieces of 1-inch round iron about eight inches long; bend a right angle in each of them; weld one arm of one of these pieces to one arm of the other, and we have one piece (Fig. 1) looking like a section of a short pair of stairs, with two rises and two treads. At the point where the pieces were joined, weld on a small ring, into which the hook of the tackle block is to catch. The lower horizontal arm is to take hold under the rings on the pipe. On the upper verticle arm, cut a thread to take an inch coupling, and you have the device.

Into this coupling a piece of 1-inch pipe was made, the pipe being long enough to reach above the surface of the water, when the siphon was bedded, and was used to remove the special hook with the tackle from the rings at the proper time. This whole arrangement served not only to save cutting the tackles but placed us in such a position, that should it become necessary, from any cause to move the siphon after it had once been sunk, the tackles could be put on again without difficulty, and the siphon moved in whatever direction desired.

Seven of these hooks were required. Long rope straps were used, one to each tackle, and the straps on the two vertical ends were left on.



Siphon on scows.



Siphon in place.

THE EFFECT OF THE AERATION OF NATURAL WATERS.

BY

Prof. Thomas M. Drown, Massachusetts Institute of Technology, Boston.

It is a very common belief that water deprived of air will deteriorate in the quality and become unfit for use and that the only way to maintain its purity is to keep it freely exposed to the air. The mountain stream which breaks over rocks and stones is thought to be a good illustration of the intimate connection between the aeration of water and its purity.

On the other hand, it is not generally known that the waters of many deep wells which we prize for their high purity, their clearness, coolness and good taste, contain no air, and have been preserved in this condition in the earth, for aught we know, for centuries. There is clearly a need of a clarification of our ideas on this subject.

Pure water, preserved from contact with organic matter, remains unchanged indefinitely. If exposed to the air it dissolves a definite amount of the gases of which the air is composed—nitrogen, oxygen and carbonic acid—the amount dissolved being dependant upon temperature and pressure. If the pressure is removed, or if the water is boiled, the gases escape, to be reabsorbed when the water is exposed to the air again at ordinary temperatures ; but in no sense does the air exert any preservative action on the water or tend to keep it "fresh" or "sweet."

The condition of affairs is, however, entirely changed when water contains organic matter which is capable of undergoing decomposition. The familiar process of the change of organic into mineral matter by decomposition is one of oxidation, and the necessity of the presence of air to carry on this change is well understood. The breaking up of organic matter when oxygen is not present is one of putrefaction, the products of which are usually very offensive.

The analogy between the comparatively slow process of oxidation in nature and the destruction of organic matter by combustion has seemed to justify the inference that we can hasten the former as we can the latter by increasing the supply of oxygen. Acting on this assumption, it is not uncommon in water works practice to aerate the water by causing it to flow over a series of steps, or by forcing it into the air as a fountain, or by pumping air under pressure into the distribution system. Whatever the method employed for aerating the water, the idea behind it is that the water will be thereby purified by oxidation to a degree beyond that which would take place if the water were exposed to the air on the surface only.

During the past two years numerous experiments have been made in the laboratory of the Massachusetts State Board of Health to test this theory of accelerated oxidation, and all the experiments have given negative results. The question, let it be clearly understood, is not one of supplying oxygen to an impure water like sewage, which contains no oxygen, but this : Will an impure water, which contains at all times more or less free oxygen

in solution be purified more rapidly by oxidation if the amount of oxgyen is increased by spraying the water or by pumping air into it; can the natural process of oxidation be hastened by these means? It is to this question that the experiments give a negative answer. If we look for the cause of this failure to hasten oxidation by increasing the amount of oxygen we find that it rests in the inherent nature of the process, a process which is only remotely analogous to the chemical process of combustion. In combustion we have the direct chemical combination of carbon and hydrogen with oxygen, and, by varying the supply of oxygen, we can at will make the combustion slow or rapid. The case is entirely different in the oxidation of organic matter in nature. Here we have to do with the living activity of bacteria, which, in some way not fully understood, causes first the carbon and hydrogen of the organic matter and then the nitrogen to combine with oxygen. This process can only be hastened by increasing the number of bacteria, or by providing more favorable conditions for their activity Thus we know that the temperature at which bacteria are most active differs with different species, but we have no evidence that, provided some free oxygen is present, the activity of the bacteria of decomposition is in the least affected by its amount. Here the analogy of bacterial oxidation and combustion ceases.

The first series of experiments was made to ascertain whether there was any change in the nitrogen compounds in waters under different conditions of aeration, namely :

(1.) By exposing water contained in bottles to the air of the room.

(2.) By drawing a current of air through the water by means of an aspirator.

(3.) By shaking the water with air in a bottle in a shaking machine driven by an electric motor the air being renewed from time to time by removing the stopper from the bottle.

(4.) By exposing the water to air under a pressure of 60 to 75 lbs. per square inch in soda water siphons.

The results of the following experiments,.shown in Tables I. and II. are given as typical of several that were made :

Table I. — Results of Aeration of Water by a Current of Air Drawn Through the Water in a Flask by Means of an Aspirator,* by Air Under Pressure, and by Shaking the water with Air in a Bottle.

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*The air used for aspiration was taken from outside the building. The air of laboratories where gas is burned contains enough nitrogen in the form of nitrites to vitiate an experiment of this character.

It was found that there was a very small amount of free ammonia taken up by pure water from the air in the cases of prolonged aeration.

First Experiment With Cochituate Waters.
(Parts per 100,000.)

	Free ammonia.	Albuminoid ammonia.	Nitrogen as nitrites.	Nitrogen as nitrates.
Original Sample	.0014	.0182	.0002	.0275
After standing in open bottle for 48 hours.	.0008	.0176	.0005	.0250
After aerating by current of air for 48 hours	.0014	.0170	.0003	.0250
After standing in open bottle for 216½ hours	.0036	.0158	.0002	.0250
After standing 49½ hours and then aerating by a current of air for 167 hours.	.0026	.0156	.0002	.0250
Fourth Experiment with Cochituate Water.				
Original Sample	.0018	.0140	.0002	.0200
After standing 72 hours	.0016	.0152	.0002	.0300
After aerating 72 hours	.0024	.0142	.0002	.0200
After being under pressure of 75 lbs. for 72 hours	.0036	.0150	.0002	.0250

Table II.—Experiments with Cochituate Water to Which a Small Amount of Sewage has been added.

(Parts per 100,000.)

	Free ammonia.	Albuminoid ammonia.	Nitrogen as nitrites.	Nitrogen as nitrates.
Original sample	.0780	.0300	.0000	.0250
After standing 6½ hours	.0720	.0326	.0000	.0250
After standing 42 hours	.0664	.0372	.0002	.0380
After standing 7 days	.0766	.0226	.0002	*.0050
After shaking 6½ hours	.0740	.0294	.0002	.0250
After being under pressure of 75 lbs. for 42 hours	.0584	.0368	.0002	.0260
After aerating 42 hours	.0400	.0402	.0003	.0260

The variations in the amounts of albuminoid ammonia and the nitrates in these experiments are in general too small to have any significance, and fall, in most cases, within the limits of accuracy of the processes used. The loss of free ammonia when the water is aerated is an instance of the driving out of one gas by another. Ammonia cannot be completely removed in this way, but when it is present in considerable amount in a water the effect of aeration by a current of air is very marked. When sewage is thus aerated a very considerable amount of free ammonia passes out with the air.

In some cases the changes in the amounts of nitrogen compounds are

*This decrease in nitrates may have been possibly due to the growth of algae in the bottle.

not easy to explain as the result of any particular treatment. The problem is a complex one. On the one hand we have the tendency of the organic nitrogen to pass into ammonia, and the ammonia to be oxidized to nitrates, and, on the other, the influence of vegetable organisms in directly assimilating the nitrogen of the ammonia and nitrates. Still, the results, as a whole, show plainly that the aeration of water containing nitrogenous matter and ammonia in considerable amount has no tendency to accelerate the oxidation of the nitrogen.

In the foregoing experiments the nitrogen compounds only were investigated. The oxidation of the carbon of the organic matter represented by the albumnoid ammonia would have as a result the formation of more free ammonia; but, as any inference based on the amount of free ammonia might be complicated by its partial removal by aeration, a series of experiments were made to ascertain directly whether any carbon was oxidized by vigorous aeration. In this series only air under pressure was used, and the evidence of the oxidation of carbon was obtained by the "oxygen consumed" from permanganate, which oxidizes only carbon and hydrogen of organic matter, not nitrogen. Should any considerable oxidation of the carbon take place by the oxygen of the air under pressure there would be a considerable reduction of the amount of permanganate used, or of the "oxygen consumed."

The results of these experiments are given in Tables III. and IV. as follows:

Table III.—Experiments on the Aeration of Cochituate Water by Air Under Pressure of 70 Lbs. per Sq. In.

(Parts per 100,000.)

	Oxygen consumed from permanganate. Without pressure, standing in open bottles.	Under 70 lbs. pressure
Original Sample	.452	...
After 24 hours	.421	.488
After 48 hours	.421	.452
After 5 days	.478	...

Table IV.—Experiment on the Aeration of Sewage Diluted with Distilled Water.*

(Parts per 100,000.)

	Oxygen consumed from permanganate. Without pressure, standing in open bottles.	Under 70 lbs. pressure
Original sample (sewage, 1 part; water, five parts)	.913	...
After 6 days	.888	.955
After 16 days	.682	.700

*The results of the many more experiments in both series will be found in full in the report of the Massachusetts State Board of Health, now in press.

Here, as in previous series, we find that no more rapid oxidation goes on when the air is under pressure in the water than when the water is exposed to the air at the surface. It may be fairly concluded from the above experiments that oxidation of the elements which go to make up organic matter is a process which can not be hastened by offering the bacteria, which are the active agents in the process, an excess of oxygen. Their activity is not stimulated in this way.

This is in accord with the interesting investigation of Dr. A. R. Leeds, who examined the water above and below Niagara Falls and found no difference in the free ammonia, albuminoid ammonia and oxygen consumed after this vigorous aeration. An interesting confirmation of the results of these experiments may also be found in the special report on Sewage Purification (Massachusetts State Board of Health, 1890) in which (pages 730-734) is given an account of experiments to determine the amount of air necessary for a good purification of the sewage by oxidation in intermittent sand filtration. When the atmosphere in the sand of the filter contained from 1 to 3 per cent. of free oxygen the oxidation was as complete and rapid as when 20 per cent. or the full amount of the atmosphere, was present.

Although the strictly chemical theory of oxidation in the aeration of water will have to be abandoned it does not follow that the practice of aeration is not without good effect. It is a well known fact that one soluble gas passed in a current through water will drive out other soluble gases which may be present in it, provided there is no chemical combination between the water and gas. The same effect is accomplished by exposing water with any gas in solution to an atmosphere of another gas. Thus when we pass a current of air through water containing sulphuretted hydrogen in solution, the latter is completely driven out, and an offensive water becomes entirely odorless. This is not a case of oxidation, for a current of carbonic acid will effect the same result. In the same way a water which has temporarily a bad odor from an excessive development of algae, or infusoria, can be rendered quite odorless by sufficient aeration. Even sewage loses its odor when aerated by a current of air for many hours In these cases the only change effected is the mechanical removal of the soluble gas which is the cause of the odor.

There is another good effect of aeration where it is accompanied by agitation of the water, namely the prevention of the growth of algae with their attendant bad tastes and odors. As is well known it is only in the comparatively quiet waters of ponds and reservoirs that this annoyance from excessive development of vegetable growth is met with. Moving waters are free from this trouble. It seems a not unreasonable explanation of the fact that an excessive growth of algae is sometimes stopped by continuons aeration to attribute it to the agitation of the water.

The most rapid means of aerating water are, first, by pumping air into it under pressure, the excess of air escaping when the pressure is removed second, by breaking it into spray by providing a series of falls, or by means of a fountain jet, or, third, by a fall, in a pipe of similar construction to an injector. But these violent methods of supplying oxygen are not neces-

sary if there is circulation in the water of a pond or reservoir whereby all the water in turn is axposed on the surface to the atmosphere.

On the advent of warm weather in the spring of the year the water of any pond over 20 feet deep may become stagnant at the bottom, and if the water contains decomposible organic matter the oxygen in solution is soon consumed and no more can be obtained from the atmosphere. Under these conditions this stagnant layer becomes very foul from putrefaction. This matter has been very fully studied in the case of Jamaica Pond, Boston, and is described in the report of the Massachusetts State Board of Health on the Examination of Water Supplies, 1890, and also in the forthcoming report for 1891.

But the water in the stagnant layer does not become foul unless there is decomposible organic matter present. Thus, in Basin 4 of the Boston waterworks, which was carefully prepared for the reception of the water by the removal of all soil and vegetable matter, and is supplied with a brown swampy water from a water-shed almost entirely free from population, the water is good at a depth of 40 feet, because the water contains very little organic matter with a tendency to decomposition.

The water is permanently stagnant during the summer months only below a depth of about 20 feet, because it is turned over by strong winds to this depth in ponds of 100 to 200 acres area. But water may be temporarily stagnant at a less depth in the absence of strong winds. In some ponds we have found oxygen to be absent at a depth of 10 feet, and the water to contain much free ammonia and other products of decomposition, which were absent in the layers nearer the surface.

In cases where it would be possible to bring about a circulation of an entire body of water during the warmer months, so that the lower layers would be brought to the surface and stagnation prevented, we would have effective aeration of the water with the prevention of the accumulation of products of decomposition.

In the case of ground water it is now well understood that the more directly from the ground it is supplied to the consumer the more acceptable it is. It needs no aeration. In fact, its storage in open reservoirs results often in the conversion of a cool, clear, palatable water into one which is repulsive to sight, taste and smell.

There is, however, one class of ground waters, not infrequently met with, which are only fit to use after they have been exposed to the air; namely, waters which contain considerable iron in solution in the form of protoxide. These waters deposit iron oxide on standing, owing to their absorption of oxygen from the air. Aeration in connection with settling basins or filter beds, might make waters of this class available for general use.

To resume :

(1). The oxidation of organic matter in water is not hastened by vigorous agitation with air or by air under pressure.

(2). The aeration of water may serve a useful purpose by preventing stagnation, by preventing the excessive growth of algae, by removing from water disagreeable gases, and by the oxidation of iron in solution.

DISCUSSION.

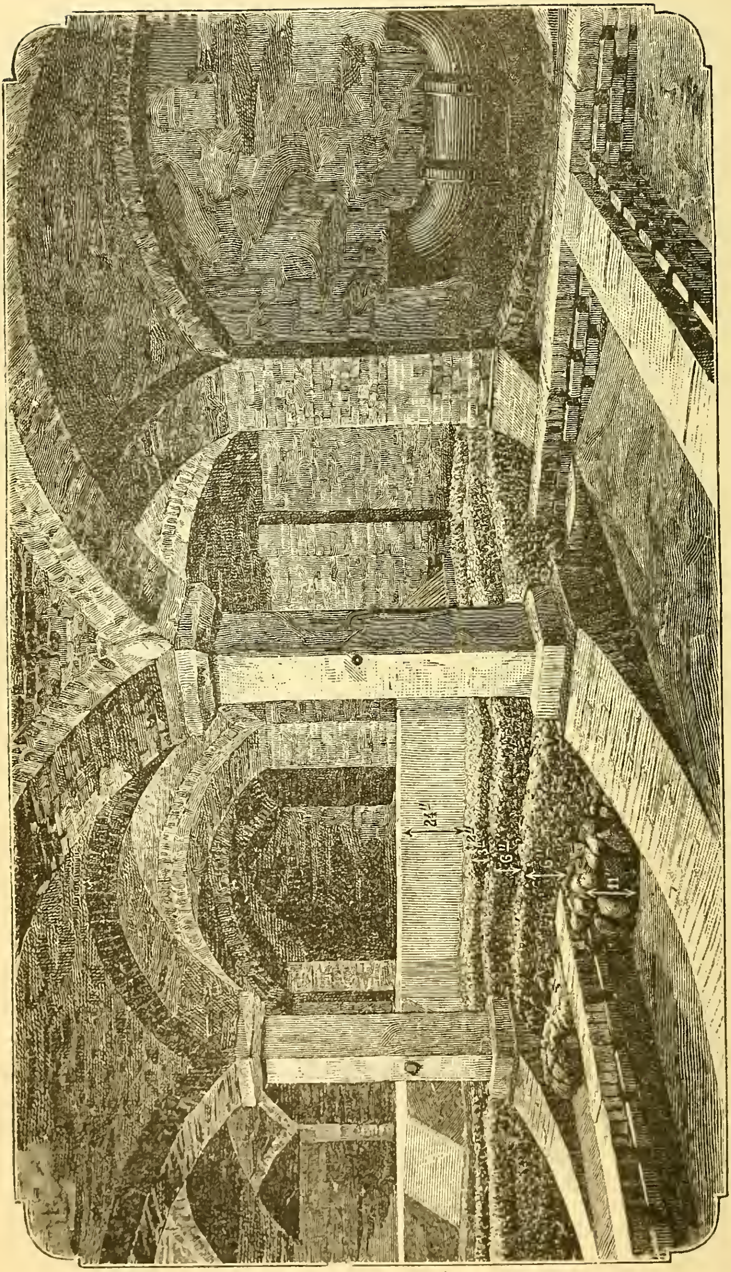
THE PRESIDENT. Prof. Drown's paper has given us a large amount of valuable information, and I would be pleased to hear something from Mr. Stearns upon this subject.

MR. STEARNS. This paper is very opportune, coming from such a source to tell us what aeration can do and what it cannot do, because I think there has been a great deal of doubt on this question in the past. It seems very clear from the paper that in the case of water that has oxygen in it, as all surface waters do, there is really no need of any aeration whatever. Prof. Drown refers to the fact that bad smelling gases in water may be driven out by the introduction of air. I know an instance of this kind where water was taken in Provincetown from a driven well. This water came from a peculiar formation, which had been made by marine vegetation and sand blown in over it, and it had a very strong odor of sulphuretted hydrogen. By putting it in a bowl and stirring it for ten minutes, giving it in this way a free exposure to the air, that odor entirely disappeared, while at first it smelt so strong that a person was careful to get to the windward side of the pump.

With reference to the stagnant water that is always found in the bottom of deep reservoirs and ponds in summer, I have made some attempt in the past to show why it is desirable to take water from the upper layers and not to get down into the stagnant water where the oxygen is used up; but last summer in several places they drew the whole of the upper layer off and then came down to the lower one which was stagnant, and they had to take that. That is, to go into matters which I have before spoken about, the surface layers are continually improving in the summer, because the algae and other growths gradually sink down into the bottom layers where there is no circulation, and where the oxygen soon gets used up by the decomposition of these algae, so the surface layers are all the time improving and the bottom layers getting bad through this putrefactive decomposition. It therefore seems desirable for any one to so plan his storage reservoirs as not to have to use that part of the water which is down more than 20 feet below high water mark, and it might possibly be a question (where it is necessary to draw deeper) whether it would not be desirable to produce a constant circulation through the summer. I don't know, however, as it is a practical thing to do.

With reference to iron in ground waters I understand that it occurs almost always in the vicinity of swamps and places where all the oxygen in the ground is used up by the decomposition of the vegetable matter, and the iron is in a ferrous state and soluble. In cases where it is necessary to use a water of this kind it is very desirable to aerate it thoroughly and filter it or give it a chance to settle before being used as a water supply. In cases where this condition exists to any great extent the State Board of Health has recommended the town to select a source where the iron was not present, thinking this course better than trying to purify such water.

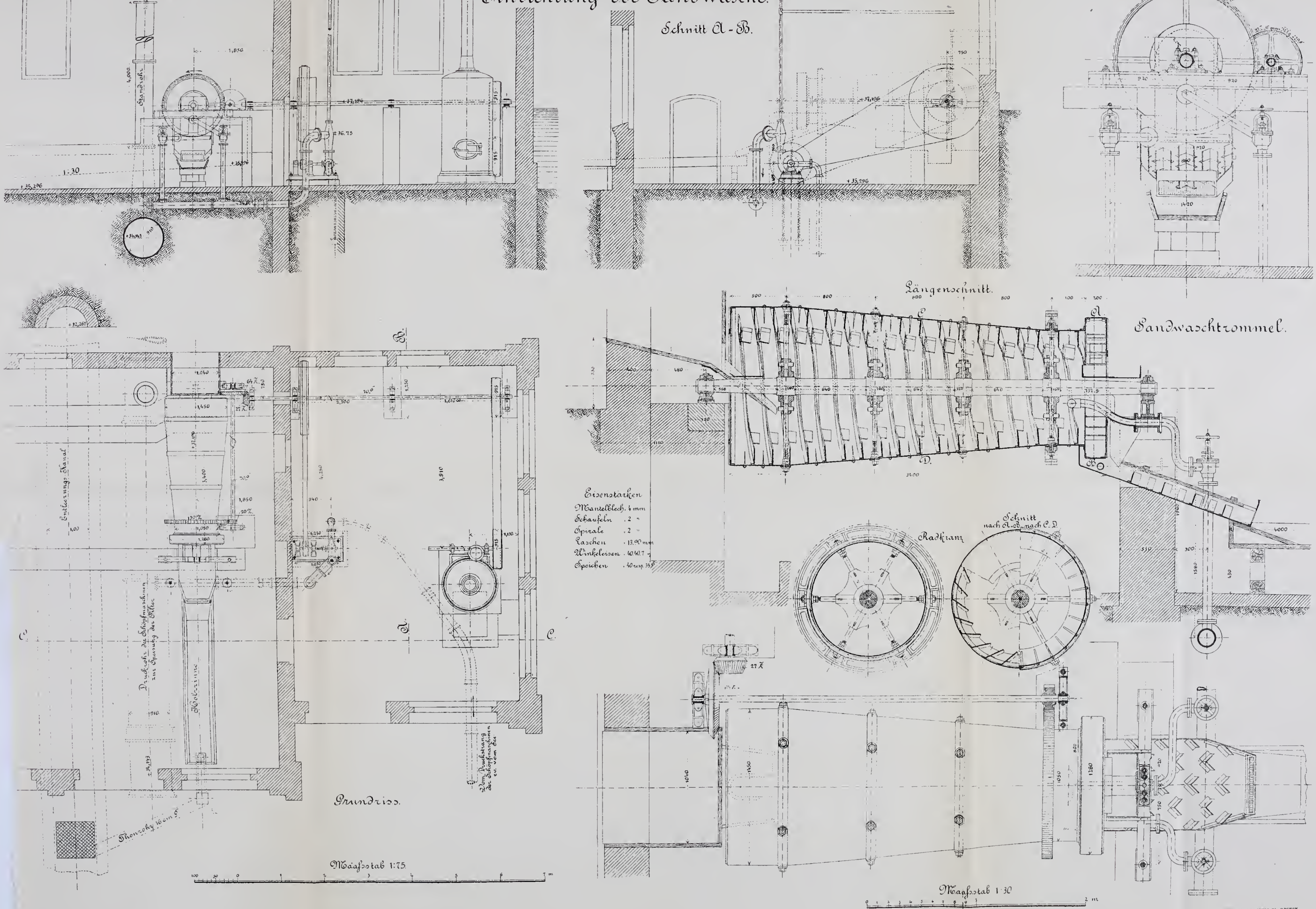
PLATE I.



A COVERED FILTER. WATER WORKS OF WARSAW, RUSSIA.
(AFTER LINDLEY.)

Wasserwerke der Stadt Berlin am Tegeler See.

Einrichtung der Sandwäsche.



THE PURIFICATION OF DRINKING WATER BY SAND FILTRATION: ITS THEORY, PRACTICE, AND RESULTS; WITH SPECIAL REFERENCE TO AMERICAN NEEDS AND EUROPEAN EXPERIENCE.*

BY

WILLIAM T. SEDGWICK, PH. D., Professor of Biology, Mass. Institute of Technology, Boston, and Chief Biologist to the State Board of Health of Massachusetts.

It has become an axiom, that one of the fundamental sanitary requirements of civilized communities is an abundant supply of pure water. To the requirement of abundance American communities have been quick to respond. The statistics of American water works testify to the energy and spirit which have furnished thousands of our cities and towns with bountiful supplies of water and with water works both extensive and costly.

There is reason to believe, however, that we have given hitherto relatively too much attention to water works and not enough to water In meeting the requirement of abundance we have done well; but in the equally fundamental and equally important requirement of purity of our water supplies we have too often failed. It is humiliating but it is true tha the sanittary condition of many of our otherwise excellent water supplies is today discreditable to American science, American engineering and American civilization. So long as the water supplies of important cities like Chicago, Philadelphia, Albany, Lowell, Lawrence and St. Louis remain in their present condition so long will they constitute a blemish upon our fair civilization.

A city or town may dig wonderful tunnels; it may build great water works or buy magnificent pumps, but if any or all of these convey impure water from fouled lakes or polluted rivers, if they occasionally deliver to the confiding citizen in his work shop or in his home the deadly germs of disease they must be set down by all sane persons as lamentable failures, because dangerous to the public health.

It is worth our while to inquire how it has come to pass that so many cities splendidly equipped with water works and ably officered, are still supplied with water that is obviously polluted with raw sewage and is shown by statistics to be a carrier of the germs of specific disease. The only explanation that I have been able to discover is the following.

Until lately the selection of sources of water supply has been largely influenced by the belief that impure water quickly, naturally, and effectually purifies itself. Again, we have often failed to foresee the growth of our own or of neighboring populations, and therefore the consequent difficulty of maintaining the purity of natural sources of supply, such as lakes and

* An Address (illustrated by stereopticon), delivered at the Annual Meeting, in Holyoke. Mass., June 10, 1892.

rivers. The latter fact is the more remarkable because as a people we have never failed to proclaim the future greatness of our cities, or the rapid strides of our population. Yet we may well believe that Chicago would have adopted a different system of water supply, if when it began to dig the first lake tunnel it had dreamed of its future greatness. We can easily believe that Philadelphia, Albany, Lowell, Lawrence and St. Louis would have sought other sources or means of supply if when their water works were introduced they had known that the self-purification of rivers is only a half-truth, and that by the use of unfiltered river water they might make typhoid fever virtually endemic within their borders.

We are but just beginning to realize the mischief which a too eager reliance upon the theory of the rapid and effectual self-purification of polluted waters has done. Half truths are often more dangerous than error. We are learning to our cost that in this case we have leaned upon a bent, if not a broken, reed. To show how slow has been the recognition of this fact we need to remember that it is only seven years since a distinguished authority referring to the polluted Mohawk-Hudson solemnly assured the people of Albany, through their Water Commissioners that "There is no reason why the city of Albany should not continue to use this water," and reaffirmed his earlier opinion that "The most careful examination of the water has failed to reveal anything to sight, taste, smell or analysis, which can be considered as throwing the slightest suspicion upon the purity of the Hudson, or its fitness for supplying a perfectly wholesome beverage for the citizens of Albany." It was only in December last that a prominent Chicago newspaper with astonishing ignorance or effrontery boasted of the magnificent water supply of that city, asserting that Chicago has at its doors an unlimited supply of the purest water in the world, to be had for the mere cost of pumping. Six weeks later the same newspaper was imploring its readers to boil the city water before drinking it, and childishly ascribing the revelation of the natural consequences of its use to an imaginary eastern jealousy.

After making all allowance, however, for the unfortunate and undue influence of the self purification theory, and for our strange inability to forsee and provide for a probable growth of population of which we were at the time loudly boasting, much still remains chargeable only to gross carelessness or indifference. The probable pollution of the Chicago water supply was officially pointed out by the State Board of Health of Illinois in 1884 and further demonstrated in 1886, but no remedy has yet been applied. Typhoid fever has long been excessive in Philadelphia; but so far as I am aware, no steps have yet been taken to remedy the evil, although there is every reason to attribute the excess chiefly to the use of unfiltered polluted river water.

Lawrence languidly discusses but has not yet begun to remedy the dangerous condition of her water supply, polluted only nine miles above the intake by the sewage of 80,000 people and further up by that of as many more. Meantime typhoid fever ravages the city, claiming relatively more victims from Lawrence than from any other city of the state. Lowell, also proceeds but slowly towards purification of her water supply which is only somewhat less objectionable than that of Lawrence. Yet it can no longer be claimed that

the dangers of polluted drinking water are doubtful or imaginary. The citizens of Paris are officially warned when the water of the Seine is about to be supplied to them. The citizens of Chicago, Lowell and Lawrence have all been warned against their public drinking water in its unfiltered condition, and we cannot doubt that those of many other cities ought to be so warned.*

The eminent statistician Korosi has recently shown in a very valuable paper that typhoid fever has prevailed to an unusual extent in Buda-Pesth within the past four years. The water supply of Buda-Pesth is drawn from the Danube, a highly polluted source. Some portions of the city receive the river water purified by sand filtration; other portions get the Danube water entirely unfiltered. Comparing certain of these districts Korosi was led to conclude, upon purely statistical grounds, that, in proportion to the population, typhoid fever was twice as abundant among those using the Danube water raw as among those who used it after sand filtration. His natural conclusion is that the substitution of filtered for unfiltered polluted waters with a view to the reduction of typhoid fever mortality, is much to be desired.

We have met tonight, however, not so much to discuss the fact or the origin of the unfortunate conditions which exist in many American cities and towns, as to consider what we can do to abate them. Here, I think, we may profit by European experience. Civilized European cities are few in which raw river water or unfiltered sewage-polluted water of any kind, is delivered to the people as their source of supply for drinking purposes. I believe that the time is at hand when in America, also, we shall cease to use unpurified water for drinking and must turn for relief to some process of purification; and I venture to predict that within the decade we shall witness the establishment of numerous and extensive municipal systems of water purification by some form of sand filtration.

The purification of water from the sanitary standpoint is the most difficult kind of purification.

The principal natural methods contributing to the sanitary improvement of water are *sedimentation, storage* and *filtration.* Light, temperature, pressure and electricity have their effects but an impure water is purified in nature chiefly by *settling,* for the bacteria have weight, and at least in some stages of their development, tend to settle; by *storage,* which has a double action shortly to be explained, and by *filtration* through the earth.

Storage has immense sanitary value and has not been hitherto sufficiently appreciated. There is good reason to believe that a water otherwise good but containing disease germs might be rendered wholesome and pure by simple storage. Under such conditions some of the bacteria settle to the bottom and eventually perish; some are destroyed by light, but the disease germs, being apparently in water somewhat short-lived, perish. It is also a fact that living bacteria largely disappear in the pipes of a service. To these facts we must look for the explanation of the limited infectiousness in some cases by water

*Since this address was made Chicago has begun to dig an immense sewage canal, which when completed, will probably improve her water supply. Lawrence has adopted a system of sand filtration and Lowell has appropriated $100,000 towards improvement of its public water supply.

obviously badly polluted with raw sewage. I am convinced that if Lawrence for example pumped directly into the pipes, as Chicago does, her death rate from typhoid fever would be far greater than it is. A recent writer has urged that sewage polluted water be drunk as soon as possible after its pollution, in order to avoid the disagreeable putrefactive phenomena which might ensue; but if what has just been said is true it is plain that to do this is to invite disaster ; it is the same kind of advice which would lead us to strain out a gnat and swallow a camel.

The sanitary value of storage is not yet, by any means, as well known as it deserves to be. Storage involves the element of time, time gives opportunity for change, and the changes which storage tends to effect in polluted water are often of the highest sanitary significance. There is no evidence that disease germs multiply in ordinary natural waters. Such evidence as we have, both from experiment and experience, indicates on the contrary, that disease germs die out more or less rapidly in good natural waters. Time, therefore, is an all important element in the sanitary improvement of infected waters, and we may safely say that infected water like wine improves with age. Here is one element of great sanitary value in storage. It may be called the vital element. Another element is sedimentation. This is mechanical instead of vital in its action, but is unquestionably of very great value in the purification of water. The germs of disease though microscopic, are material, and they are subject to the law of gravity. They are also easily dragged down by heavier masses in their settling, and a muddy water may on standing purify itself to a remarkable degree merely by settling. Thus storage, by bringing in the element of time, allowing the disease particles to die out, and by favoring sedimentation, is of immense sanitary value, while settling basins for muddy waters not only clarify, but to a greater or less extent also actually purify the water which passes through them. It is probably for this reason that St. Louis has fared as well as it has hitherto. Particularly valuable is the storage of flood waters because in times of flood infectious material is more rapidly transported than usual from point to point. The great water companies that so ably supply the wants of the largest city in the world make a special point of the storage of the flood waters of the Thames and the Lea, and that they are right in doing so the vital statistics of London amply demonstrate.

I know that there is another side to the storage question. I know that stored waters exposed to the light are apt to become troubled by unsightly and ill-smelling growths. I know that if the latter provoke disgust or nausea in the consumer the sanitary value of storage is justly called in question. But in spite of these drawbacks, which cannot be overlooked, it is still true that storage, by favoring sedimentation and giving time for specific disease germs to die out, is, nevertheless, from the sanitary standpoint, of great value in the purification of polluted waters.

To recapitulate : *sedimentation* is a valuable means of the purification of water and has its sanitary value in removing disease germs from flowing or standing water. St Louis has great settling basins in which the muddy water of the Mississippi is settled. Here in addition to their own tendency to fall by gravity the removal of the disease germs is probably greatly aided by the

falling particles of mud which drag them down. *Storage* is of great sanitary value, first by giving time and opportunity for sedimentation and secondly by giving time for the disease germs to die out. New York doubtless derives much sanitary advantage from her great storage system. Neither of these methods of purification, however, is entirely trustworthy. If the storage is too brief some germs will survive; if the sedimentation is incomplete the effluent from the settling basins will still be unsafe.

There is another natural method, however, which is more common and more trustworthy. This is *filtration* through the earth or sand. I do not need to do more than to remind you of the pure spring which pours from the earth, germ free, its sparkling water originally the rain or snow but since filtered through deep layers of the earth; or of well waters which in spite of their occasional privy and barn-yard origin are, as a rule, free from the germs of disease. Yet these are really filtered surface waters, and in their history we may discover the secret of the more extensive purification of great bodies of water, such as lakes and rivers. The fouled waters of barn yards if run off upon the farmer's meadow become purified. Even the more solid stable manure thickly spread upon the field if committed to the earth and turned under by the plow readily disappear. These examples and the more familiar results of burial show how the earth—the living earth, as it has been well called—teeming as it is with bacteria and other micro-organisms, purifies organic matters, even when they are in the fluid state. But apart from this vital action, earth, and especially sand, is an excellent strainer. Ordinary loam is too fine and soon gets clogged, but sand especially after it has become partly clogged is a capital filter, for it works rapidly and yet so effectively as to retain even the bacteria in the pplied liquid. Long before the immense purifying capacity of sand filtration could be demonstrated scientifically it had been proved by experience. Wells sunk in the earth have been known from the earliest times, and have often given excellent water though sunk in regions in bad sanitary condition. When in 1850 the dangerous pollution of the Thames and the London water supply was demonstrated by Dr. Hassall, by means of the first systematic microscopical examination of a public water supply ever attempted, the remedy applied was storage and sand filtration. The steady improvement in the sanitary condition of London, which is today the wonder and the envy of the world, is due in no small measure to the protection afforded by her now very extensive system of sand filtration. I am myself persuaded that in scientifically conducted sand filtration we have a complete solution of the problem of a safe and sanitary water supply. I am ready to agree with Fraenkel, the professor of hygiene at Marburg and Piefke, the accomplished engineer of the Berlin-Stralau water works when they affirm that:

I. *Every surface water, before it is used for drinking purposes, should be freed from all infectious substances.*

II. *For this purpose, whenever large quantities of water are to be treated, sand filtration is at present the most convenient and effective method.*

It is not claimed that all waters need to be filtered, but when a city or town is so unfortunate as to be obliged to use a polluted source of supply there can be no question whatever as to the requirements of modern sanitary science; the water must first be freed from infectious materials. For this purpose there is nothing better known to sanitary science at present, than scientifically conducted sand filtration.

It is said that sand filtration was first introduced at Chelsea, near London, by James Simpson in 1839. At the time of the celebrated microscopical examination of the London water supply by Dr. Hassall, in 1850, the water supplied to London was indeed "filtered" by the companies, but so badly that it was scarcely strained, for Dr. Hassall found fish and many smaller objects in the filtered water. After much debate and many inquiries a *Water Act* was passed for London in 1852 which prescribed effectual filtration and storage of the London water supply, to be in operation in 1855, regulated the charges and made other arrangements between the citizens and the eight water companies. The results obtained were so good that the rules then adopted have been followed upon the continent, and the English practice has since served as a model here, as in other branches of sanitary science, to the rest of Europe and to the world. Reserving for the end of this paper a more complete account of the English practice as exemplified in London, let us turn first to the purification of the water supply of the German capital, Berlin. This city has now a population in round numbers of one and one-half millions and it has probably the best examples of sand filters to be found on the continent. Berlin is supplied from two sources, one a lake, Lake Tegel, and the other a river, the Spree, which, below the intake, passes through the city. We may first describe the older establishment, that at the river, known as the Stralau Water Works, under the able administration of C. Piefke, whose studies upon the theory and practice of sand filtration have placed him among the very first of European sanitary engineers. I am personally indebted to Herr Piefke for his courtesy in offering me every facility to study the operation of the Berlin-Stralau Works on the occasion of my visit to them in 1891. I have also his permission to make use of his published accounts of his work.

SAND FILTRATION OF THE PUBLIC WATER SUPPLY OF BERLIN.

(A.) THE STRALAU WATER WORKS.

The general location and plan of the filters which purify the water of the Spree are shown on Plate No. II. The position of the two intakes is shown at *a* (the older) and at *b* (the more recent). From *a* the water flows by gravity to the pumps along the line indicated. From *b* the water is drawn directly by the pumps. From these it passes in a common main along the lines *l l* to the several filters, but as it is impossible to adjust the pumps to the varying demands of the filters this supply main ends in a small supply or compensating (*Vorraths*) reservoir shown on the northern border of the filters. When the pumps are not working the supply for the filters is drawn from

this. Its capacity is 11,000 cubic meters (2,906,000 gallons.) This reservoir with the open filters No. I.-IV., near by, represents the oldest portion of the plant. Originally it served in good measure as a settling basin, but as new filters have been added, this function has gradually diminished until now the daily output of the plant far exceeds the capacity of the reservoir and it serves as little more than a regulating or compensating reservoir of unfiltered water. It is but just to say that owing to the enormous growth of Berlin the present system is said to be decidedly overtaxed. More filters should be added immediately, and I am informed that steps have been taken looking to this end. Since 1873 the Stralau works have consisted of 37,067 square meters (about nine acres) of filtering surface, arranged in eleven independent sections or basins. They may be worked separately or together. The normal maximal output of the whole plant is placed by Piefke at 60,000 cubic meters (15,850,000 gallons) every 24 hours. But sometimes, on special occasions, it has been as much as 70,000 or even 80,000 cubic meters (18,000,000—21,000,000 gallons.) Three of the filters (Nos. IX.-XI.) having a combined area of 9,000 square meters (2.2 acres) are covered, to guard against severe and prolonged cold weather. In winter the daily consumption (from this plant) sinks as a rule to 30,000 cubic meters (7,925,000 gallons.) It ought to be said, at this point, that the newer Tegel Water Works (to be described beyond) supply a comparatively fixed quantity of filtered water to Berlin, summer and winter alike. The extra demand of the summer falls, therefore, largely upon the older works at Stralau, and these are at times plainly overtaxed, giving too rapid filtration with incomplete purification.*

The filtered water is drawn off beneath the several filters by under drains which convey the water to a reservoir for purified water (*Reinwasser*) placed at such a depth as to receive the effluent by gravity. (See Plate II. and Plate V. Figs. 1 and 2.) This has a total capacity of only 2,200 cubic meters (581,000 gallons.) The sand washing establishment, which at Berlin, is regarded as a most important feature is located in the angle between filters No. VI. and No. IX. (Plate II.) The engine and boiler houses, the Office, and the dwellings of the resident engineer, etc., are shown in section on the street front (Plate II.)

The intake located at *b* on Plate II. is shown in elevation, plan, and sections on Plate III. and requires no special remarks. *The filters* are shown in sections (transverse and longitudinal) on Plate IV. Fig. 1 shows a longitudinal section through the under drain. Fig. 2 is a cross section showing the (central) under drain, the overflow waste pipe and the general arrangement and construction of the filters. For the details of the construction I must refer the reader to the original paper of Piefke. Suffice it to say that the bottom must be water tight and the sides strong enough to support the pressure of the enclosed water. Those at Berlin-Stralau are laid upon clay (*Thon*) covered with concrete (*Beton*.) (See Plate IV., Fig. 2.) Fig. 6

*These and the following data are taken from Piefke *Aphorismen uber Wasserversorgung* II. Zeit fur Hygiene, VIII., 1890.

is a section through one of the covered filters (Plate II., Nos. IX.-XI., showing the piers, arches and the openings to admit light during the process of cleaning the filter. Piefke remarks, however, that for cleaning, artificial light is on the whole to be preferred to the scanty daylight which can be admitted in this way. The actual filtering materials used at the Stralau works and resting upon the concrete, are as follows, beginning at the top:

Fine Sharp Sand	22 inches
Coarse Sand	2 "
Fine Gravel	6 "
Medium Gravel	5 "
Coarse Gravel	3 "
Small Stones	4 "
Large Stones	12 "
Total	54 inches

It is interesting to compare this construction with that of the London filters shown in the tables beyond (see Appendix pp. 4-7) as well as with the sand filters of Zurich and Warsaw (p. 115) and the Berlin-Tegel works (p. 113.) Piefke expressly states that he does not consider a greater depth of sand to be of much advantage, provided that the sand shall be sharp, and he believes that more time and trouble is often spent upon these details of the actual filtering materials that is necessary. The under drains connect directly with the lower layers of the filter so that while the water sinks vertically through the sand it flows laterally through the coarser underlying layers. From time to time the filter must be drained for cleaning. If it is not desired to drain it completely but only for scraping the very surface, the valve shown at v in Plate IV., Fig 2, and connecting with the overflow (u) may be opened. If it is desired to drain the filter thoroughly another valve known as the "sand cock" (*Sandhahn*) shown in elevation in Fig. 4 and in section in Fig. 5 may be opened. I must pass over many interesting details of the actual management of the filters which are fully described by Piefke in the paper referred to. Numerous automatic devices for detecting the precise conditions at any particular moment, and for aiding the superintendent, have been introduced at Berlin; but for these also I must refer the reader to the original paper.

The ordinary process of filtration is conducted as follows: After a filter has been worked for a time it is found to have become clogged and allows the water to pass through only very slowly. The arrival of this time is shown by an automatic tell-tale float (w) seen in section in Fig. I. If, with the valve k closed, this float rises but very slowly it is clear that in spite of a high pressure of the supernatant water (h) only a little passes through the sand. The filter is then described as "dead" and must be cleaned. It is therefore drained and a gang of men is set to work on it with broad thin shovels, or with special "scrapers" A plank track is laid on an incline down into the basin and the scrapings are taken away in wheel barrows to

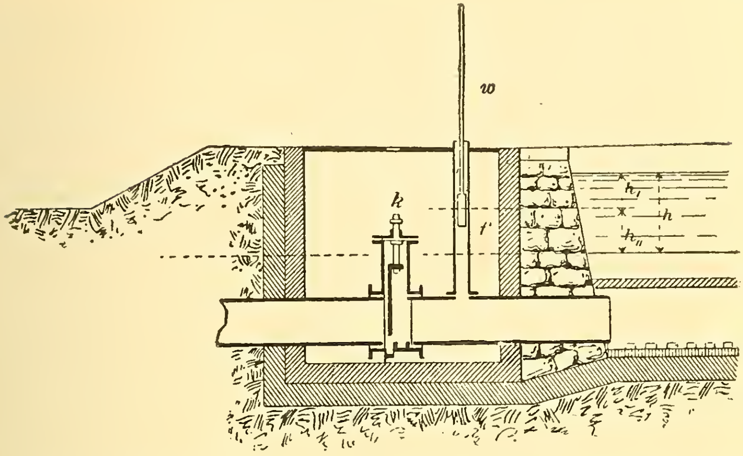


FIG. 1. Tell-tale float w in use at the Berlin-Stralau Water Works. The output of the filter, regulated by the gate k, remaining constant the height of w will indicate roughly the degree of resistance, or clogging. (After Piefke.)

the sand-washing house. At the time of my visit a gang of perhaps thirty men was cleaning a filter. Only the uppermost layer of sand and the dirt deposit upon it was removed. This dirt deposit or *Schmutzdecke* is extremely interesting. In Berlin I found it to consist of a thin membranous layer of a greenish brown color and so well defined that it could be easily peeled off in flakes from the sand below very much as a moistened postage stamp can be peeled from a piece of paper to which it has become partially attached. The sand below the *Schmutzdecke* was clean and white to a very noticeable and striking degree, so that it was obvious that only the *Schmutzdecke* required to be removed. Carefully detached by the scrapers it was drawn up into little heaps of a peck or a half bushel each and these were carried away on the wheel barrows to the sand washing establishment. Once the *Schmutzdecke* has been removed and the life of the filter is restored, the sand is smoothed, the filter slowly filled from below (with clean water) to drive out all air and prevent fissures or channels, and the whole covered with unfiltered water to the depth of about 3 or 4 feet through the inflow pipe. (Plate IV, Fig. 3.) Meantime the outlet is kept closed so that the supernatant water stands quietly upon the sand and is allowed to settle. This is a point of much importance as the consequence of this settling is the formation of a delicate membrane or new *Schmutzdecke* upon the clean sand. After a time, varying with the demands upon the plant, the effluent is allowed to escape, fresh unfiltered water flows upon the filter and filtration proceeds. At first it is, of course, rapid and comparatively imperfect, but as the membranous deposit (*Schmutzdecke* thickens, it grows slower and yields a

better effluent. The filtration continues with increasing head and diminishing rate until the *Schmutzdecke* becomes almost impervious when the filter is said to be "dead" and once more ready for cleaning.

By the kindness of Herr Piefke I was able to examine carefully the *Schmutzdecke* both *in situ* and microscopically. It consisted of much brown amorphous matter (zoogloea), numerous filaments of algae giving to the whole its dark greenish tinge and its firm felted or membranous character, besides particles of woody fibre, debris, etc. The smooth and almost slimy feel of the membrane appeared to be due chiefly to the algae and the zoogloea. The membrane was perhaps 1-8—1-16 inch in thickness. I have described the *Schmutzdecke* (surface deposit) in some detail both because I was much impressed by its well defined character and position and also because, according to Piefke, this membranous deposit is the principle factor in efficient sand filtration. One who sees it as I saw it (towards the end of August, 1891) upon an open but "dead" filter cannot help perceiving that such a micro-membrane must indeed play a most important part in continuous filtration. From its peculiar composition and semi gelatinous character, it must be highly effective in the detention of all suspended particles of whatever kind, including bacteria. When the *Schmutzdecke* is so well defined as it usually appears to be at Berlin the sand below it looks bright and fresh. At the Stralau works the depth of sand may well be thought to be of secondary importance, the real filter being the micro-membrane. Whether it is always of so little importance may be more open to question.

Naturally, at Berlin, the scraping is so arranged as to remove as little sand each time as possible. Gradually, however, the sand layer grows thinner and after a time it must be replenished with new (or washed) sand to the original depth. This happens about once in two years, and requires considerable time. Even the ordinary scraping requires that the filter shall be out of connection for several days. At some seasons scraping is required (in Berlin) very often (once a week) but in winter very seldom (once in two or three months.) The Spree is not muddy like the Mississippi but at times is very unclean and in summer contains vast quantities of certain algae which are particularly troublesome, making an almost impervious "felt" through which the water moves only very slowly.

The Sand Washing. This is done at Berlin because it is found to be cheaper than to import new sand. The position of the sand washing establishment is shown on Plate No. II. Some of the details of the apparatus employed are shown on Plate No. VI. Fig. 1 shows the ground plan, and Fig. 2 the section. Fig. 3 is the revolving drum in which the sand is washed. Fig. 4 is the section A-B on Fig. 1. Figs. 5 and 6 shows sections of a centrifugal pump. This is a very interesting portion of the work but space forbids me to enter upon it in detail. Piefke states that all of the filters are cleaned perhaps twenty times annually, and that about ⅓ of the filtering material has, therefore, to be washed or otherwise renewed, yearly.

(B.) THE BERLIN WATER WORKS AT LAKE TEGEL.

To keep pace with the growth of Berlin and the increasing consumption of water a new and separate establishment was in 1877 added to that at Stralau and located on the other side of the city, by the southern shore of Lake Tegel. The following account of the Tegel Water Works is drawn almost exclusively from the admirable account of the works given by the resident engineer, G. Anklamm, and published with additions, as a reprint from *Glaser's Annalen fur Gewerbe und Bauwesen, Bd. XIX. Berlin*, 1886. I have ventured to reproduce from this two of Anklamm's admirable and instructive plates. (See Plates VII. and VIII.) Plate No. VII. shows the general location and plan of the Tegel works with some details of construction of the (covered) filters. Plate No. VIII. shows the several parts of the sand washing apparatus.

Originally the attempt was made to obtain a supply of pure water without filtration from the shores of the lake by sinking there a number of wells. These at first yielded an excellent supply, but after a time the water deteriorated owing to the growth in the wells and in the mains of an iron-bearing bacterium *Crenothrix*. This grew to such an extent in the Tegel water supply as to constitute what has been called "The Berlin Water Calamity." To obviate the difficulty Commissions were appointed, investigations were made, aeration and other means of relief were attempted, but without avail. At length about 1883 sand filters were established to treat the water taken from the lake and these, ever since their installation, have yielded an admirable effluent. When they were first put in operation the mains and service pipes contained an abundant vegetation of *Crenothrix* but little by little this disappeared in the presence of the filtered water. The area of the four larger filters is in round numbers 2500 square meters (27,000 square feet) each, that of the six smaller ones 2000 square meters (21,000 square feet.) The total filtering area is about 22,000 square meters (236,700 square feet or between five and six acres. The normal yield of the filter is placed at three cubic meters of water or each square meter of filtering service for twenty-four hours or roughly at 3,000,000 gallons per day per acre. Seven of the ten filters are usually running at once and serve to furnish the requisite quantity of filtered water. The other filters, three in number, serve as a reserve and also for use in the summer time, when the life of the filters is shorter. The filters are all covered, and in order to keep a temperature as low as possible in summer, they are covered with a layer of earth forty to seventy centimeters thick ; this layer is covered with grass.

The filtering material consists of three layers. The lowest is about thirty centimeters thick, of rounded granite stones ; upon this there rests a layer about thirty centimeters thick of coarse clean river gravel free of sand and upon this a layer about sixty centimeters thick of medium coarse sand. The average diameter of the sand grains is about $\frac{1}{3}$ of a millimeter. Before the material is placed in position it is carefully cleaned from clay and dirt by special washings. Each filter is fitted with an under drain, with feed pipes, etc. The filter is filled as at Stralau from below in order to drive out the air

particles contained in the sand. This filling must be done slowly for otherwise air will remain in spite of it, and will interfere with the successful operation of the filters by forming during its escape, canals, through which organisms can penetrate into the under layers of sand or gravel.

After the filter has been operated for some time a gelatinous layer (*Schmutzdecke* of Piefke) is formed of such imperviousness that each square meter of surface will no longer furnish as much as three cubic meters (800 gallons) of water in twenty-four hours. When this time has arrived the filter must be scraped, but before the supply is cut off the feed valve is opened wide for a few minutes in order to clean out the feed pipe, and wash away the snails, mussels and deposits of dirt, etc., which accumulate in it. In some cases it is said that as many as twelve hectoliters (several bushels) of snails and the like have been washed out of a single feed pipe. After the valve has been closed and the water has sunk to a depth of fifty or sixty centimeters upon the filter the outflow valve of the under drains is also closed, and the water still upon the filter is run off through the waste pipe. The thin layer of dirty sand to the depth of ten or fifteen millimeters, ($\frac{1}{3}$—$\frac{1}{2}$ inch) is then removed by means of broad sharp shovels, and wheeled off to the sand washing machine. After removing this portion of sand the filter is once more filled with water from below, and set in operation. As a rule, however, this is not done at once; whenever the demand for the filter is not too great it is allowed to rest after cleaning for some time, in the belief that those particles of the dirt deposit (*Schmutzdecke*) which have penetrated unto the lower layers will be oxydised under prolonged contact with the air. In order to facilitate this operation, special attempts are made to secure a certain circulation of the air in the filtering materials. The life of the filters is naturally comparatively brief in the summer months. While it rises as high as eighty days in the winter, it sinks in midsummer, at the time of the so-called "water blossoming," not infrequently as low as ten days. On an average for the year, it is about thirty days. Replenishing with new or clean sand occurs comparatively seldom, and only after the sand layer, originally sixty centimeters thick, has been gradually worn down to thirty centimeters.

The regulating apparatus at the Tegel filters is of great interest; and for the orderly management of the filters is extremely important. It will be seen at a glance that a new filter, as yet unclogged, will offer much less resistance to the passage of the water than an older filter more or less clogged that is, covered with the *Schmutzdecke*. It becomes necessary, therefore, to work an old filter under greater head, and in order that the output shall remain constant, this head must be gradually increased. Special devices to accomplish this end, have been introduced by Henry Gill, Esq., chief engineer of the entire Berlin water supply, by W. H. Lindley of Frankfurt, and by others. Some of these will be described beyond.

I have entered somewhat at length into descriptions of the Berlin filters because they are probably, on the whole, the most carefully planned and most thoroughly studied of any filters on the continent. I may now briefly refer to a few other continental sand filters.

SAND FILTERS AT WARSAW, RUSSIA.

The source of the public water supply of Warsaw is the river Vistula. The water is first run into settling basins, and then upon the filters. The capacity of the filters is about 2.4 cubic meters per square meter of surface, every twenty-four hours. Plate No. I. at the beginning of this paper shows the arrangement of one of the (covered) filters at Warsaw. It will be seen that upon eleven inches of stones, there are six inches of smaller stones, above these six inches still smaller, and upon this layer three inches of coarse gravel, covered by two inches of fine gravel, and the whole surmounted by two feet of fine sand. The passages for the filtered water are shown as spaces between the bricks on the right of the figure. The feed pipe is also shown on the right. At Warsaw it is not customary to wash the sand, as at Berlin (and many other places) fresh sand being found to be cheaper. At Warsaw a filter of 2100 square meters area, was scraped by fifteen men in ten hours, and replenished with new sand by the same number of men in four days. The depth of water upon the filters at Warsaw is kept at 1.2 meters.*

SAND FILTERS AT OPORTO.

Sand filters have been provided for Oporto by *the Compagnie generale des eaux* of Paris. The water is taken from the river Souza. The arrangement of the filters is as follows: The supporting layer consists of stones (large) .15 m., stones (small) .15 m., upon which come first coarse sand .10 m., and fine sand at the top .20 m., making a total of .60 m. The total area of the filters is 1190 square meters, with a normal depth of water of .90 meters. The filters yield on an average 13 cubic meters of water per square meter for twenty-four hours. This system is said to be open to much criticism, probably from its slight depth of sand and high rate of filtration.

SAND FILTERS AT ZURICH.

In consequence of an extensive epidemic of typhoid fever in Zurich in 1884 which was traced to the pollution of the public water supply, a water commission was appointed and prepared a report recommending the installation of a system of sand filters. They advised that water should be taken from the lake (Zurich) at least 200 meters from the shore, and filtered upon sand filters at the rate of six to eight meters (vertical water column) per day. Inasmuch as the requirement of the city was only about 20,000 cubic meters daily, they estimated that a filter area of 3000 or 3500 square meters would be sufficient, This enormous rate of filtration was recommended because of the comparative initial purity of the lake water. It was recognized, however, that extra land should be secured, so that by extension of the plant even with increased consumption the rate need not exceed more than three meters

*For a more complete account of the Warsaw filters and a full and admirable statement of the problem of the purification of river waters for drinking purposes, see W. H. Lindley, *Vierteljahr. fur Oeff. Gesundhheitspflege*, 1890, p. 191. Also, an abstract in this Journal, Vol. 5, p. 33, 1890.

per day. In December, 1885, three of the five filters were in operation, and in the following August the fourth and fifth were added. The combined area of the five filters was 3500 square meters. For extension of the plant space was reserved to the extent of 75,000 square meters. Filters number one, two and three are covered ; numbers four and five are open ; all five have the same area with about 672 square meters of effective surface. The filtering material lies upon a solid foundation covered with two layers of brick, and consists from below upwards of the following layers : Five to fifteen centimeters of coarse gravel, upon this ten centimeters of garden gravel carrying fifteen centimeters of quite coarse sand, which is surmounted by eighty centimeters of fine sand. The regulation of the rapidity of filtration is accomplished for each filter separately. When the head or difference in level between the filtered and unfiltered water reaches sixty to eighty centimeters cleaning of that particular filter generally takes place. Cleaning consists in draining off all the water and scraping away the uppermost sand layer with iron shovels to the depth of about two centimeters. Experience shows that only a thin slimy layer (*Schmutzdecke* of Piefke) covers the otherwise clean sand and that this layer is only a few millimeters in thickness. After cleaning, the filter is filled from below with filtered water and once more filtration proceeds. The water which first comes through after cleaning is, however, rejected during this early period and the dirt carried up from the sand by the water after filling and which consists of floating particles of slimy material, is removed as far as possible by letting it run off from the top before filtering begins. In 1887 the cleaning was necessary, on an average, for the covered filters every forty-eight days. As a result of these periodical scrapings the layer of fine sand gradually grows thinner, and when it has sunk so that it is only fifty centimeters in thickness, it is either replenished with clean sand up to eighty centimeters or it is taken out altogether and replaced by a fresh sand layer of the original thickness. This renewal of the filtering material did not become necessary until after the end of 1888.*

SAND FILTERS IN ROTTERDAM.

The city of Rotterdam takes its water supply from a tidal stream, the Maas. Into this stream the sewage of the city also flows. By the situation of the intake and the time of taking in water for filtration, most of the danger of sewage contamination from Rotterdam itself is supposed to be avoided. The Maas, however, is by no means a pure source of supply, and it is often, if not usually, very muddy. The water is first passed into large settling basins to which it flows by gravity. From the settling basins it is lifted by pumps and afterwards flows upon a series of sand filters. Owing to the limited capacity of the works, and to the large consumption of the city, the water is not allowed to stand in the settling basins as long as is considered desirable and the filtration is far more rapid than the superintendent regards as proper. The effluent is now clear, bright and entirely unobjectionable in appearance, and has never

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*The foregoing statements are taken largely from *Bertschinger*, *Wirkung der Sand Filter in Zurich*, 1889. See also *Journal fur Gasbeleucht. und Wasser versorgung*, 1891, p. 684.

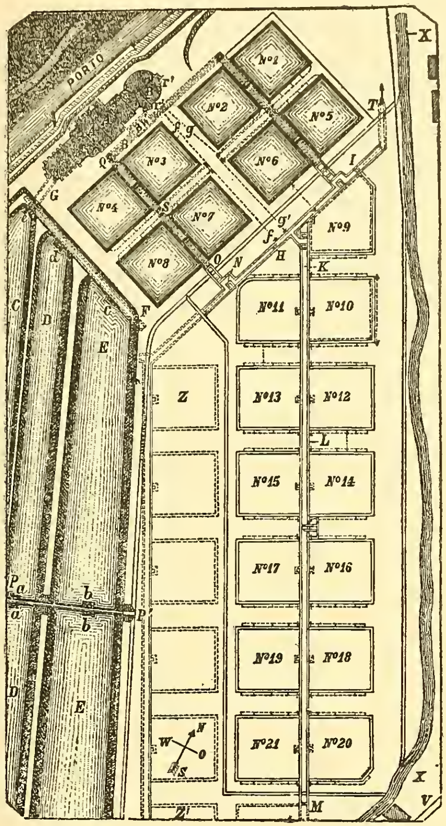


FIG. 2. The Sand Filters of Rotterdam, Holland. Nos. 1–8 the older filters. Nos. 9–20 the newer filters. *C, D, E,* settling basins. The pumping station is shown on the border of the canal (Port.) To it water is drawn from the settling basins, and from it water flows to the several filters. (After DeVries.)

caused complaint in the city until a few years since, when the whole system became filled with the much dreaded "pest of water works" *Crenothrix.* This produced complaint, and such a deterioration in the water as to excite the greatest anxiety on the part of the pbulic as well as of the officials. Professor DeVries of Amsterdam has published a valuable account of the investition made by himself and other members of the commission which sought to discover the cause of the evil and a remedy for it. Professor DeVries concluded that the imperfect settling, the excessively rapid filtration, and the existence in some places beneath the filter of old wooden beams, etc., all taken together allowed a sufficient quantity of organic matter to pass into the mains to support a luxuriant vegetation of *Crenothrix.*

I visited the works at Rotterdam in the summer of 1891, and it was obvious to me, that in comparison with the sand filters at Berlin, those at Rotterdam were insufficient and overworked. I am unable to give exact figures as to the

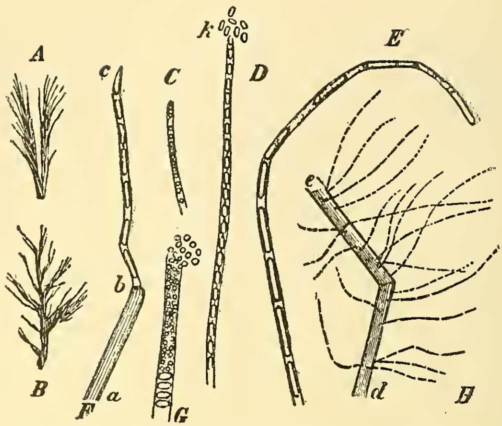


FIG. 3. *Crenothrix Kuhniana.* An Iron-bacterium. *A, B,* flocks or clusters of the plant as it comes from drains or filters. *H,* single threads growing from an older encrusted thread. *C, D, E, F, G,* various stages in its growth and reproduction. (After DeVries.)

depth of the sand, the intervals of scraping, the rate of filtration, the daily yield, etc., but the general construction of the sand filters was similar to that of the Berlin filters. It was noticeable, however, that here the well defined *Schmutzdecke* of Berlin was absent. The sand appeared dirty to a consider-

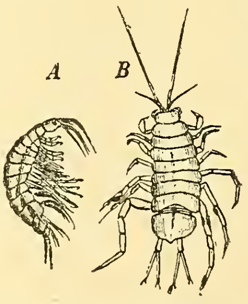


FIG. 4. Small Crustacea which occurred in great numbers in the filtered water at Rotterdam during the Crenothrix calamity. (After DeVries.)

able depth and there was every evidence of overworked filters treating a water originally much worse than any that I had seen. I am under great obligations to Mr. Vogel, the engineer, in charge who showed me every courtesy.*

Enough has now been said of actual sand filters on the continent but as to their operation and their efficiency something may still be said. In

*For a full account of the *Crenothrix* Commission see De Vries's paper, of which an abstract (in English) was published by me in the *Technology Quarterly*, Vol. III., p. 338, 1890.

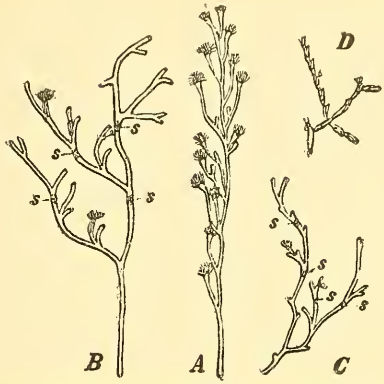


FIG. 5. Moss-like animals (*Bryozoa*) growing in abundance in the conduits of unfiltered water at Rotterdam. (After DeVries.)

September, 1890, there occurred at Brunswick the annual meeting of the German Public Health Association. At this meeting the subject of sand filters for municipal water works was fully discussed by Fraenkel, the distinguished bacteriologist, and Piefke, the accomplished Resident Engineer in charge of one division of the water works of Berlin. The Stralau Water Works as has been shown above are managed with great skill by Piefke, and consist of an elaborate system of sand filteration, the water being taken from the river Spree. Professor Fraenkel and Engineer Piefke incited by an epidemic of typhoid fever which broke out in Berlin in 1889, had come to the conclusion, after careful experimentation upon artificial filters with special bacteria including some of the germs of disease, that contrary to the general belief, it was possible under certain circumstances for disease germs to find their way through sand filters like those in use in Berlin.* Impressed by the importance of their results they formulated the following conclusions which they made the text of special addresses at the Public Health Association meeting just mentioned :

I. Every surface water before it is used for drinking ought to be freed from all infectious materials.

II. For this purpose in all those cases in which large quantities of water have to be treated, sand filtration is to be regarded as at present the most practicable and the most satisfactory method.

III. The operation of sand filters is not, as has been widely assumed always entirely trustworthy and under all circumstances satisfactory. A sand filter is not a germ tight apparatus ; but by intelligent manipulation it is possible to reduce this defect to a very insignificant quantity.

IV. To accomplish this end there are necessary :

(*a.*) Good raw material (unfiltered water) as little polluted as possible.
(*b.*) A low rate of filtration.
(*c.*) Uniform action of the filter.
(*d.*) Rejection of the effluent at the beginning of a new period of filtration.

*See *Technology Quarterly*, Vol. III., p. 69, 1890.

These theses were ably defended by Fraenkel and Piefke at the meeting, but as might have been anticipated, aroused vigorous opposition. Up to this time it was apparently a common belief among the water superintendents and engineers in Germany that sand filters necessarily removed completely or detained, all of the suspended matters of the unfiltered water not excepting the bacteria. It was with this idea that the Zurich filters were established and Bertschinger believed that the few bacteria in the effluent from these filters had come from the stones, the under drains and outlet pipes, and not through the filter. His ideas probably well represented the state of opinion among water engineers in Germany, up to the time of the experiments of Fraenkel and Piefke. They were supported also by the sanitary experience of London, and by English experience in general, for it had been found unquestionably true, that filtration was a great sanitary safeguard ; but until the experiments of Fraenkel and Piefke no one in Europe had undertaken to discover, by an application of special cultures of known bacteria to sand filters, whether these could, or could not, be discovered in the effluent.

The experiments of the State Board of Health of Massachusetts made in 1889, and published in 1891, were the first experiments of this kind ever made, and they proved conclusively that bacteria may, under special circumstances, pass through sand filters operated intermittently. The experiments of Fraenkel and Piefke were the first which demonstrated the same possibilities for continuous filters.

The allegation that sand filters might not be an absolute surety against the passage of disease germs, aroused a vigorous debate at the meeting referred to in September, 1890, and met with strong opposition. It was urged more or less effectively that the experimental filters of Fraenkel and Piefke, having been made of wood, and the same filter having been run at different rates, their conclusions were based upon abnormal conditions and were untrustworthy. Piefke has since repeated the experiments under conditions adapted to meet these objections, and has obtained results confirmatory of the earlier experiments. The truth seems to be that sand filters if well managed are a complete sanitary safeguard, but that they require intelligent management to produce the highest results. The experiments of the State Board of Health of Massachusetts, at the Lawrence experiment station have been conducted for a longer time, and with greater care than any experiments elsewhere, or hitherto, and these show conclusively that the results of Fraenkel and Piefke are probably sound. A sand filter is not necessarily a germ tight apparatus, but it is entirely possible to construct and operate sand filters in such a way as to render filtered water safe for domestic use and for drinking purposes.

The address of Engineer Piefke at the meeting referred to* is full of interesting matter concerning sand filtration. He begins by saying that one of the indispensable requisites for success is that the rate shall remain constant, and not depend upon the variations of the consumption during the day. We may get an excellent illustration of the range of this variation in

*The report of this part of the meeting is very interesting and I have drawn largely upon it in the preparation of this paper. It is to be found under the title:—"*Filterantagen fur Stadtische Wasserleitungen*," in the *Deutsche Vierteljahr. fur Oeffentliche Gesundheitspflege*, *Bd.* 33, 1891.

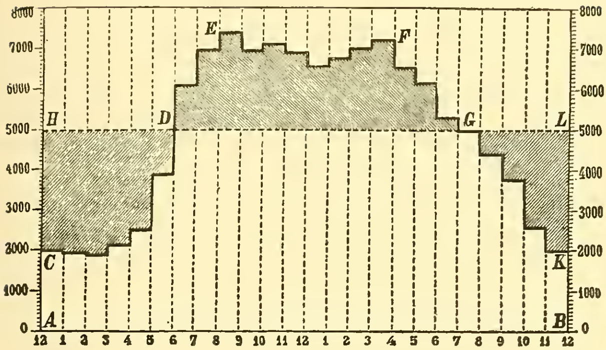


FIG. 6. Hourly consumption of water in Berlin, August 21, 1889. The ordinates indicate cubic meters; the abscissas indicate hours, beginning on the left at midnight. The average hourly consumption (5000) is shown by the horizontal dotted line. (After Piefke.)

consumption if we follow hour by hour the history of the water supply of a great city, on any particular day. In Berlin for example the daily consumption from the two water works (Tegel and Stralau) on the 21st of August, 1889, was 120,000 cubic meters or 31,701,600 gallons. The average, therefore, was 5000 cubic meters or 1,320,900 gallons per hour. The actual consumption per hour varied, however, so much that at midnight it fell 64 per cent. below the average, and during the day it rose about one-half above it. The greatest consumption was between 8 and 9 a. m. and 3 and 4 p. m. The smallest between 2 and 3 o'clock a. m. These variations in their range and distribution can be conveniently followed by the help of the diagram (Fig. 6) which is self explanatory. It follows obviously, that the filters must supply in the night too much, and in the day too little water. It therefore becomes necessary to introduce between the filter and the point of consumption, a reservoir in which the excess filtered during the night, can be reserved as a store for use during the day, the time of maximum consumption. This reservoir may be called the compensating reservoir.

For Berlin, under the conditions prevailing at that time, Piefke estimated by an examination of diagrams such as we have just given, that a compensating reservoir of at least 25,000 cubic meters (6,604,500 gallons) actual capacity was required. In fact the Berlin reservoirs actually hold more than 30,000 cubic meters (7,925,400) gallons and consist of three quite independent sections, so that if one of them needs to be thrown out of connection, the other two may still suffice. Piefke recommends that the reservoir for filtered water should be covered, not only to avoid disturbance through the accumulation of ice in winter but especially to exclude light. In filtered waters exposed to the light various algae and other organisms

flourish and affect more or less unfavorably by their growth the water which has been so carefully purified.

Piefke next considers the proper operation of the outflow and inflow of sand filters. There appears to be no special difficulties in the regulation of the inflow, by the watchman for if the filter receives by mistake at any time too much water the excess can escape through the overflow pipe. (See Plate IV. Fig. 2, *u*) More complex is the management of the effluent in prescribed quantities; this requires the assistance of hydrometric apparatus. Let us suppose that a filter of two thousand square meters area is required to work throughout a certain period at the rate of one hundred vertical millimeters (4 inches) per hour. This will regularly furnish two hundred cubic meters per hour. When it is possible to measure and control at any instant the filtered water flowing off it becomes possible to adjust the filter to its duty. A very convenient method of measuring the water is the one in which it is allowed to flow off out of a spacious tank, through a horizontal slit in a vertical wall. The slit should have, in proportion to its width, an insignificant height. The quantity of water which escapes through the slit, depends upon the height of the water above the upper border of the slit. This we may call the head. Different amounts of head naturally represent special amounts of effluent. If the height of the water above the slit is fixed then it is evident that the hourly discharge of water will always be the same. For different quantities of effluent, corresponding head can be computed, and after this has been once done a scale can be prepared, which, fixed in position, shall instantly show at what point the water level must be in order to obtain a certain quantity of water in a unit of time.

Use is made of this principle in an apparatus which has been much employed for several years under the name of the "Gill" regulator and which is shown on Plate V., Figs. 3 and 4. From the covered filter shown on the right of the figure, filtered water passes through the underdrain *c*. Under the gate house, at *s*, can be seen the slit through which the water flows out freely; a few centimeters above this is the water level computed for the normal or desired rate of filtration ; it is plainly marked upon a scale, and for control there is a float which rises and sinks in a tube and carries by a chain over a pulley an automatic pencil. The indicator must not leave the place computed for it, if the filtration is to be constant. A new and more serviceable form of Gill's regulator permits the filtration and supply to be brought very accurately into relation with one another.

The Gill regulator works satisfactorily and permits the operation to go on at any prescribed rate of filtration, but its use pre-supposes intelligent service on the part of a watchman. As this may be regarded as an objection we may turn, says Piefke, to the consideration of automatic regulators. An example of these is that devised by Lindley (see Fig. 7) for the recently constructed filter works at Warsaw Lindley provides each filter with a walled but un-partitioned gate house. The filtered water rises in this to the proper height and carries a heavy float. Firmly fixed to the latter is

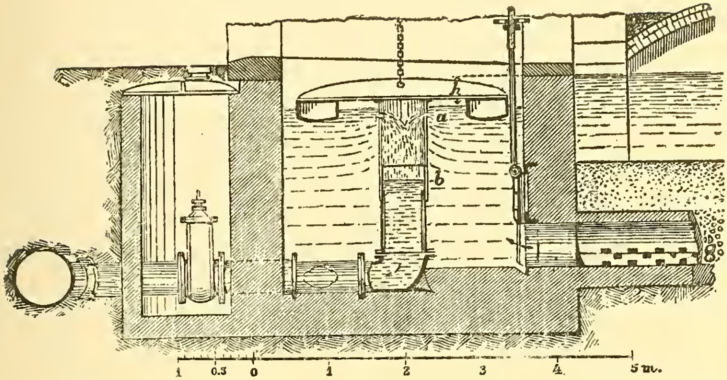


FIG. 7. Automatic regulator employed by Lindley, at Warsaw. The (covered) filter is shown with its underdrain, on the right. For details consult the text. (After Lindley.)

the telescopic tube *b* closed at the top. This naturally shares in all vertical movements of the float, rises and sinks as this does and thus moves up and down over the fixed tube below, which is open at the top and is also shown in Fig. 7. On account of its fixed weight, the float sinks always to the same depth in the water whatever may be the height of the water level in the gate house. If now below the level of the float, we make two elongated slits or openings in the wall of the tube, these will keep at a constant depth beneath the surface of the water, and always allow the same quantity of water to flow off into the tube. Any variation will occur only in case the slits themselves are changed, which is effected by an external moveable ring.

For the maintenance of an even working of the filter, it is required further, that for every portion of filter surface, which for cleaning or any other reason, is thrown out of operation, an equally large area shall be provided as a substitute. The size of the reserve surface involves difficulties which constitute one objection to filtration. Since by cleaning the filter there is removed every time a thin layer of sand, and the sand layer gradually grows too shallow it must after long use become unfit for further operation, and has to be replenished; a task which usually demands several weeks. For this reason also reserve filtering areas should be provided. The surfaces which are provided are usually found successively in different stages of preparation; a part is being cleaned; a part is being worked; and a part is being supplied with fresh sand. Theoretically one may say that the reserve surfaces provided should be three times of the actual filters. Their proportion to the active surface is, however, not constant, but can be discovered only by experience; diminishing obviously with the rapidity of filtration. The objection brought against a low rate of filtration is mainly the financial

one. In his recent paper, Lindley has made valuable statements concerning the cost of construction of filter plants. He gives especially the cost in Berlin and Warsaw, and concludes with the following facts; estimates carefully corrected give for a large establishment of covered filters having 48,000 square meters of filtering area in round numbers 67 marks or 84 francs ($16.75) per square meter. A similar computation for open filters with the same materials and the same price for labor, showed that these would cost about 45 marks or 56 francs ($11.20) per square meter; that is two-thirds as much. The covering of filters thus means on the Continent an increased cost of 50 per cent. Lindley quotes the actual cost of the Berlin filter at Stralau at 64 marks, and at Tegel 68–72 marks per sq. meter. He cites early English experience as indicating a cost of $10–$13 per sq. meter, everything included.

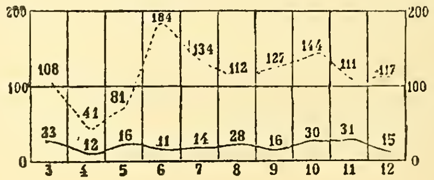


FIG. 8. Bacteria discharged in September, 1884, from a covered filter (broken line) and an open filter (solid line) in Berlin. The numbers upon the wavy lines indicate the number of bacteria per cubic centimeter. The numbers at the bottom indicate the days of the month. (After Wolffhugel and Piefke.)

Piefke then proceeds to a discussion on the relative advantages of covered and open filters, and shows that the open filters are more effective from a bacteriological point of view or at least that the out-put of bacteria from them is smaller. He gives a diagram (Fig. 8) showing these facts. The main objection to open filters is that in winter they cannot so readily be cleaned on account of the freezing of the sand, but Piefke claims that by selecting a warm "spell" for cleaning, it is quite possible (in Berlin) to avoid complications from this source, and the English experience certainly confirms this idea. It is to be remembered that the consumption of water is much smaller in winter, than in summer, and also that the life of the filter is correspondingly longer, owing to the absence of the more bulky vegetable growths of the summer. It seems probable that the greater bacterial efficiency of the open filters is due to their easier clogging which, of course, signifies a shorter "life."

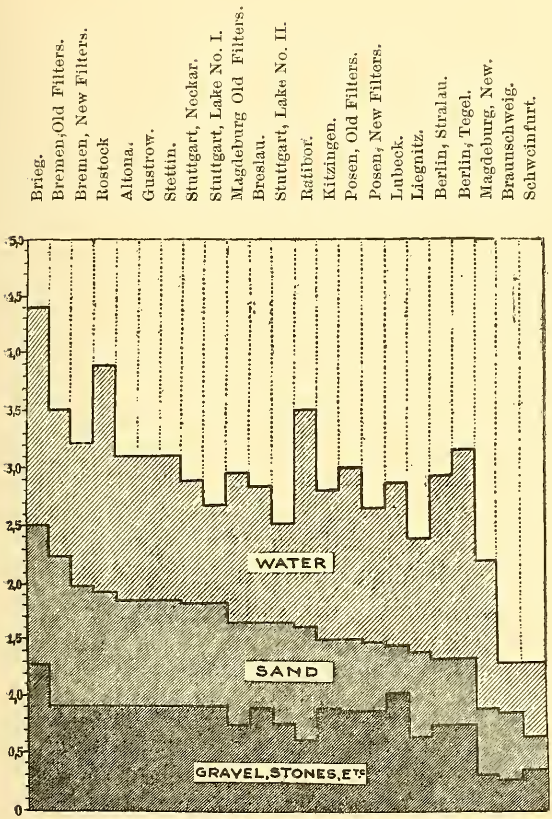


FIG. 9. *(After Kummel).* A diagram showing the depth of the filtering materials and the usual depth of unfiltered water upon the sand filters in use in certain cities and towns of Germany. The figures on the left indicate meters. It will be observed that the depth of the sand varies widely in different places.

As has been said above (p. 120) the addresses of Fraenkel and Piefke provoked much comment and their views met with considerable opposition. In the course of the debate Engineer Kummel, director of the water works at Altona, introduced some highly instructive diagrams which are here reproduced in Figs. 9 and 10.

More recently Piefke has repeated the experiments upon which his earlier conclusions were based and in such a manner as to meet all objections. The results entirely confirmed those of his previous experiments. There is no reason to doubt that a sand filter is not necessarily and under all circum-

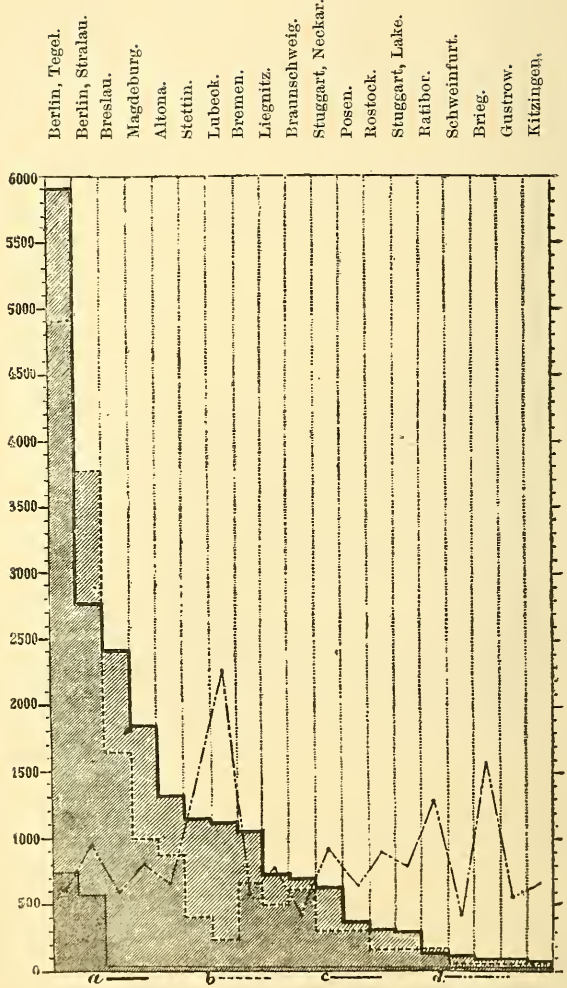


FIG. 10. (*After Kummel.*) The broad solid line [a] indicates one-tenth of the average number of cubic meters filtered daily [1 cu. metre=264.18 U. S. gallons.] The dotted line [b] indicates one-tenth of the square meters of filtering area. The narrower solid line [c] indicates one-tenth of the average area of filter surface cleaned daily. The broken line [d] indicates ten times the rate of filtration per hour in millimeters.

stances a germ proof apparatus. But it is equally plain that with proper management it may become germ tight and that even when not as carefully operated as it should be it is often very nearly germ proof. Its function as a sanitary safeguard is therefore of the highest importance, and that it has already attained great efficiency in this direction vital statistics abundantly prove.

I have already alluded to the fact that we owe to the State Board of Health of Massachusetts the first proof that bacteria may pass through a sand filter, and to Fraenkel and Piefke the first proof that bacteria may pass through during the continuous filtration of water. More recently the State Board of Health of Massachusetts has been experimenting at great length upon the removal of disease germs from the water of the Merrimac river as received at the Lawrence experiment station, both by intermittent and by continuous sand filtration. The results thus far obtained are highly satisfactory, and will soon be made public in the Report of the board. I may say, however, that it has already been found possible to remove all the germs of typhoid fever from the water of the Merrimac river by filtration through sand at a rate which readily places this means of purification within the reach of ordinary American cities. I would earnestly recommend to those interested in this subject that they fully inform themselves concerning the important researches in this direction now going on at the Lawrence experiment station of the State Board of Health of Massachusetts, under the direction of Hiram F. Mills, Esq., the distinguished hydraulic engineer, who is a member of the Board and Chairman of its Committee on on water supply and sewerage.

SAND FILTRATION OF THE WATER SUPPLY OF LONDON.

I have kept for the last the most important example of sand filtration in the world, namely, that of the public water supply of London. The water supply of London gradually became so objectionable that in 1852 it formed the subject of legislative interference which was destined to have a far-reaching influence not only upon London but upon the whole of Europe. In this year was passed the now well-known *Water Act*, which provided for a Metropolitan supply, granting the privileges of such supply to eight private companies, but requiring them to locate their intakes on the Thames above the influence of tidal flow and above the influence of London sewage, and prescribing effectual filtration. A portion of the *Act* runs as follows :

"From and after 31st August, 1855, every reservoir within a distance in a straight line of St. Paul's shall be roofed or otherwise covered over, except storage reservoirs for collecting the water before filtration, and except reservoirs for water used for street cleaning or fires, and not for domestic use.

"From and after 31st December, 1855, every company shall effectually filter all the water supplied by them within the metropolis for domestic use, excepting any water which may be pumped from wells into a covered reservoir or aqueduct without exposure to the atmosphere."

Instead of entering upon a detailed description of the London filters, which would require more space than I can command, I have ventured to reproduce in reduced fac simile one of the monthly reports upon the London Water Supply, taken at random, namely, that for May, 1892. This will be found in the *Appendix* to this paper, and upon pp. 4-7 of the *Appendix* is given a concise tabulated and comparative statement of the system, its extent, the depth of the filters, the amount of storage capacity, etc., etc., which has seemed to me peculiarly valuable inasmuch as it gives in great detail a description of the means by which the greatest, and probably the healthiest city in the world is served with drinking water, chiefly through sand filtration. The population supplied is now about 6,000,000, and the area of the sand filters employed for London is 109¾ acres.

It ought to be said that the water supply of London is still in the hands of the eight water companies to which it was given in 1852; and, furthermore, that extreme care is taken to secure, as far as possible, the cleanliness of the Thames by a special Board, the *Thames Conservancy Board*, which protects the purity of the water above the intake. By more recent acts these companies are required to submit the filtered water to the examination of an expert chemist employed by the Metropolis, though they also employ on their own part other chemists. For many years the chemist for the city has been Dr. E. Frankland, from whom a report appears in the fac simile, as does also one from the companies' present chemists, Messrs. Crookes and Odling.

I have introduced this (reduced) fac simile principally to show the great care and pains taken to secure for London a pure water supply. It naturally follows that the cost is also great. But I am of the opinion that the last place for economy should be in the matter of a supply of pure drinking water; and I believe that the time is at hand when American towns and cities must have pure drinking water at whatever cost. To accomplish this will require in many cases not only increased expenditure but also more expert administration.*

RESULTS OF SAND FILTRATION.

I have now given some account of the present theory and practice of sand filtration, and it only remains to consider its results. These are so obvious and so important as to challenge our attention and compel our admiration. The most convenient standard that we have for measuring the sanitary effect of a water supply is the mortality of the community from diarrhœal diseases. The reason for this is that these are naturally the diseases which contaminate sewage and which might be expected to travel in sewage-polluted drinking

*Those who wish to read further concerning the Water Supply of London may consult the following: *Quarterly Review*, 1892, p. 63. *Nineteenth Century*, 1892, p. 224. *Contemporary Review*, 1892, p. 26. *Fortnightly Review*, Vol. 36, p. 378. *The Monthly Reports on the Metropolitan Water Supply. The Annual Reports of the Local Government Board.* In the paper in the *Quarterly Review* [which contains much of value] further references will be found. I would also refer the reader upon the subject of filtration to *Kirkwood's* most valuable Report on the *Filtration of River Waters*, New York, 1869.

waters. Good examples of these diseases are Asiatic cholera and typhoid fever. The eruptive diseases such as measles, scarlet fever, and small pox, or the throat diseases such as diphtheria, cannot be expected to travel so readily in this way. Of all the diarrhœal diseases, typhoid fever is the best standard for our purposes, and I know of no disease which offers so good a measure of the sanitary condition of a community in respect to its water supply as this does. If now we compare the death rates from typhoid fever of such cities as London and Berlin having (in great part) river supplies filtered through sand, with those of American cities such as Philadelphia, Albany, Cincinnati, St. Louis, Lowell and Lawrence having similar supplies unfiltered, we shall find a very great difference in favor of filtration. Some of the results of such a comparison are given in a recent paper by Mr. Allen Hazen and myself, upon Typhoid Fever in Chicago.*

From a careful study of the figures and diagrams there given it will appear that London and Berlin compare very favorably with cities having great storage reservoirs, such as New York, and it is a fact that London has a death rate from this disease as low as that of many cities having unobjectionable supplies. I may also refer again to the results of Korosi's studies upon Buda-Pesth, (see above, p. 105), while Bertschinger has shown in his latest paper, referred to above, that with sand filtration of its water supply Zurich has become much less affected with typhoid fever. There is no reason to doubt that if Paris could subject the water of the Seine to sand filtration before delivering it as it occasionally does to the citizens for drinking purposes, many deaths in that city from typhoid fever might be avoided.

Postscript—One of the most striking phenomena of the recent cholera epidemic in Hamburg was the exemption of the closely connected city of Altona. Both are on the Elbe. Both use the Elbe as the source of their water supplies. But in Hamburg the only system of purification is the use (nominally) of settling basins. In Altona the water is purified by sand filtration. The Hamburg system is overworked and the water is scarcely allowed to settle at all. The death rate from typhoid fever has for years been high in Hamburg. During the recent epidemic of cholera Hamburg suffered severely while Altona, though very near it, on the same side and below it on the river, was virtually exempt.

Plate IX., (after Reincke) may serve to give a good idea of the remarkable instance furnished by Hamburg on the one hand, and Altona-Ottensen on the other. Fig. 1 shows the general situation of Hamburg, the main sewer outfalls of Hamburg and Altona, and the position of the intake of the Hamburg water works. Fig. 2 shows the intimate relations of Hamburg and Altona and also the location of the intake and the sand filters of Altona-Ottensen, some eight miles down the river at Blankenese. During the cholera epidemic of 1892, Hamburg with a population of 622,530 had 17,975 cases and 7,611 deaths from Asiatic cholera. Altona with a population of 143,000 had during the same period 562 cases and 328 deaths. The intake of the Hamburg water works is

*Engineering News, April 21, 1892.

about two miles above the city, but, it is said, not so far that the flood tide may not carry to it the sewage of Hamburg-Altona. The Elbe at Blankenese contains all the impurities present at the Hamburg intake, plus the sewage of Hamburg and Altona. Yet Altona suffered but little from cholera while Hamburg suffered severely. The Imperial Board of Health of Germany, in a recent publication, attributes the comparative exemption of Altona to the fact that its water supply was effectually protected throughout the epidemic by sand filtration.

On the other side of Hamburg from Altona lies the city of Wandsbeck (see Plate IX., Fig 1) with a population of about 20,000. Although it adjoins Hamburg it enjoyed an exemption similar to that of Altona, having had only 64 cases and 43 deaths from the cholera. Moreover, in the case of Wandsbeck and Altona there was every reason to suppose that the cases which did occur were imported from Hamburg, and not due to the local conditions. According to the Imperial Board of Health Wandsbeck is supplied with water, not from the Elbe, but from two inland lakes, the water from which is first subjected to thorough sand filtration and then delivered to the citizens. It is further stated that during the epidemic the sand filters of Altona were carefully watched and were worked at a low speed in order to secure complete protection against the disease.

It is cited by the same authority as a proof that the Hamburg water supply was infected that certain streets of Hamburg adjoining Altona were served by the Altona water works, and that these streets remained unaffected during the epidemic. So als› did a portion of the garrison at Hamburg which used well water of good quality, while another portion supplied with the Hamburg water was attacked with cholera. As the very latest example of the beneficent sanitary results of sand filtration, the case of Altona is well worthy of the most serious consideration.

Those of our American cities, such as Chicago, Philadelphia, Albany, Lowell and Lawrence, which regularly supply to their citizens fecalized water, *i e*, water liable to contain bowel discharges, may reasonably feel no small anxiety after the sad experience of Hamburg with fecalized water in 1892.

APPENDIX

AND

PLATES.

REDUCED FAC-SIMILE OF

THE REPORT OF

THE METROPOLITAN WATER SUPPLY.

LONDON, ENGLAND.

MAY, 1892.

REPORT on the Condition of the Metropolitan Water Supply during the month of May 1892, by the Water Examiner appointed under the Metropolis Water Act, 1871.

The results of the Census of 1891 have shown that estimates of the increment of the population of Registration London for, at any rate, the later years of the decennium 1881–1891, based on the actual increments of the decennia 1861–71, 1871–81, which which have been used to some extent by the Metropolitan Water Companies in calculating the populations supplied by them, have been largely in excess of the actual increment. Since the publication of the preliminary census report and tables, the East London and Grand Junction Companies have furnished returns, in which large reductions in the figures of population supplied, as compared with earlier returns, have been made. Moreover evidence given in June 1892 before the Royal Commission on Water Supply has given rise to doubts in regard to the accuracy in other respects of the statistics of houses, population and water, supplied by some of the Companies to the Water Examiner. The subject is admittedly a difficult and complicated one, and even when the greatest care is exercised estimates can only be considered approximate. As the question is undergoing competent investigation the figures given in this report and the tables which follow must be considered to be, in the respects referred to, merely provisional and liable to considerable modification hereafter.

The Thames water at Hampton, Molesey, and Sunbury was in good condition during the whole of the month. At its highest point the water was 6 inches above, and at its lowest point 3 inches below the average summer level. The total rainfall during the month at West Molesey was 1·27 inches.

The average daily supply delivered from the Thames during the month was 98,925,329 gallons; from the Lee, 59,085,636 gallons; from springs and wells, 30,160,144 gallons; from ponds at Hampstead and Highgate, 287,417 gallons. The last is used for non-domestic purposes only. The daily total was, therefore, 188,458,526 gallons for a population aggregating 5,579,111, representing a daily consumption per head of 33·78 gallons for all purposes.

The relative proportions of the supplies from the above various sources were as follows:—

From the Thames - - - -	52·49 per cent.
„ „ Lee - - - - -	31·35 „
„ springs and wells - - - -	16·01 „
„ ponds - - - - -	0·15 „

The following statement compares, in the case of each Company, the number of gallons per head per day supplied during the month, with the number supplied during the same month of the previous year:—

—	May. 1892.	May. 1891.
Chelsea	36·80	35·91
East London	36·55	37·69
Grand Junction	47·49	47·70
Kent	30·73	29·07
Lambeth	29·66	28·86
New River	30·89	28·43
Southwark and Vauxhall	33·46	30·22
West Middlesex	30·79	31·07

The total number of houses supplied by the Water Companies during the month was 784,643, representing an increase of 1,275 supplies on the previous month.

The total supply divided by the number of houses shows a daily average of 240 gallons for each tenement.

In the following statement the per-centage of house supplies on the constant system in each Company's district on the 31st December 1891, and at the end of the month are compared:—

—	31st Dec. 1891.	31st May. 1892.
Chelsea	23 per cent.	30 per cent.
East London	98 „	98 „
Grand Junction	75 „	75 „
Kent	56 „	57 „
Lambeth	53 „	55 „
New River	44 „	47 „
Southwark and Vauxhall	77 „	82 „
West Middlesex	43 „	46 „

The general result of the joint operation of the Companies and Authorities is shown by an increase during the month to the extent of 5,159 in the number of houses on constant supply, making the total 522,298, or about 67 per cent. of the total number of houses supplied.

The number of miles of streets containing water-pipes constantly charged in each Water Company's District within the Metropolis is as follows:—Chelsea, 80; East London, 185; Grand Junction, 85¼; Kent, 158¼; Lambeth, 171; New River, 308; Southwark and Vauxhall, 160; West Middlesex, 120½; Total 1,268 miles. Throughout this extent of streets, hydrants for fire purposes can be fixed.

A comparison of the number of miles of streets with mains constantly charged as entered in column 19 of the table following, with the number of public hydrants returned in column 20, will show what progress has been made within the Metropolis in meeting requirements for the more efficient protection of property from fire.

From the statement given by Dr. E. Frankland in his report on the analyses undertaken by him during the month on behalf of the Local Government Board, it appears that organic carbon was present in the samples of filtered water analysed by him, in proportions ranging for any unit of weight from 0·021 units to 0·126 units in every 100,000 units of the water. The chemists carrying out analyses for the Water Companies show by their results, which are recorded in the Appendix, proportions of organic carbon ranging from 0·048 units to 0·143 units in every 100,000 units of the water.

The proportions of brown tint in samples observed in a 2-foot tube, ascertained by their comparison with a standard tint of brown opposed to 20 mm. in thickness of blue tint, in the manner described in the report for October 1887, ranged from 1 mm. to 11 mm.

Referring to the report of the Companies' chemists, it will be seen that the water of the Southwark and Vauxhall Company showed the highest average amount of organic carbon, while that of the New River Company showed the lowest amount. The analyses made by Dr. Frankland on behalf of the Local Government Board

showed that the sample of water drawn from the mains of the Southwark and Vauxhall Company contained the highest proportion of organic carbon, and that of the Kent Company the lowest.

The water of the Southwark and Vauxhall Company exhibited the deepest average tint of brown.

In the following table the circumstances under which filtration was carried out during the month by each Company are compared, and the condition of the samples of water is also indicated.

Names of Companies.	Filtering Area per Million Gallons of Average Daily Supply.	Thickness of Sand.		Average Rate of Filtration per Square Foot per Hour.	Area of Filter Beds cleaned during the Month.
		Maximum.	Minimum.		
	Acres.	Ft. in.	Ft. in.	Gallons.	Acres.
Chelsea	0·68	4 6	4 0	$1\frac{3}{4}$	2
East London	0·67	2 0	1 3	$1\frac{1}{8}$	29
Grand Junction	0·96	2 0	1 8	$2\frac{1}{16}$	$12\frac{1}{4}$
Lambeth	0·48	3 0	2 4	$2\frac{1}{6}$	$8\frac{1}{4}$
New River	0·50	2 3	1 5	$2\frac{1}{20}$	$19\frac{1}{2}$
Southwark and Vauxhall	0·55	3 0	1 9	$1\frac{1}{2}$	14
West Middlesex	0·88	3 3	2 3	$1\frac{1}{3}$	$16\frac{1}{4}$

The water delivered by the Chelsea, East London, Grand Junction, Lambeth, New River, and West Middlesex Companies, was found on examination to be effectually filtered. The water of the Southwark and Vauxhall Company at Battersea Works was also effectually filtered. The water issuing from the filters of this Company at Hampton on the 23rd of May contained suspended matter consisting mainly of vegetable fibre. Three-eighths of the available area of filters were thrown out of use for cleaning.

The following statement shows the number of days' supply represented by the capacity of the reservoirs for unfiltered water belonging to each Company :—

Chelsea	14·2
East London	13·7
Grand Junction	3·5
Lambeth	6·5
New River	5·1
Southwark and Vauxhall	2·5
West Middlesex	7·0

The relative positions here assigned to the Companies, in regard to their means of avoiding the introduction of flood-water to their filters, must, however, be qualified in certain cases to a considerable extent. The New River Company avails itself largely of well-water, and the River Lee, above its intake, is less fouled by floods than it is lower down the valley. The Southwark and Vauxhall, and the Grand Junction Companies, have the resource, during floods, of pumping from the gravel beds adjoining the Thames, and this is practically equivalent to an addition to their provision of storage-reservoirs. Nevertheless, under existing circumstances, turbid water must of necessity be sometimes admitted, and filters are then overtaxed. The Southwark and Vauxhall Company are engaged in the construction of additional filters at Hampton, and rapid progress is being made.

In the tabular statement which follows, details are given under 26 heads in reference to the subjects noted on above, as well as a number of others of interest which relate to the appliances and works of the Companies dealing with the Metropolitan Water Supply.

The Report of Dr. E. Frankland, F.R.S., on the analyses undertaken by him during the month, on behalf of the Local Government Board, will be found at page 8 of the Appendix to this Report; and is followed by a communication addressed to the Official Water Examiner by Messrs. Wm. Crookes, F.R.S., and Wm. Odling, M.B., F.R.S., with reference to the results of analyses undertaken by them at the instance of the Directors of the Seven Water Companies deriving their supplies from the Thames and the Lea. No analysis of the water supplied during the month has been furnished by the Kent Company.

Statistics of the Metropolitan Water Supply and Works

Name of the Company.	Intake.	Situation of Works.	*Total Volume which may be drawn daily. Gallons.	Average Daily Supply during the Month. Gallons.	Approximate per-centage delivered for other than domestic purposes.	Number of Supplies to Houses, &c. returned.	Number of Houses on constant Supply.	Estimated Population supplied within the Districts of the Water Companies.	Subsiding and Storage Reservoirs for Unfiltered Water. No.	Area in Acres.	Available Capacity. Gallons.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Chelsea Waterworks.	From the Thames at Ditton and Molesey.	- - - - - -	22,000,000	10,606,274	20 exclusive of waste.	35,358	10,872	288,195	—	—	—
		Molesey	—	—		—	—	—	4	40	140,000,000
		Seething Wells	—	—		—	—	—	—	—	—
		Putney Heath	—	—		—	—	—	—	—	—
		Total of Chelsea Waterworks	22,000,000	10,506,274	—	36,358	10,872	288,195	4	40	140,000,000
East London Waterworks.	From the River Lee and Thames at Sunbury, and Chalk Wells and Springs.	- - - -	From Thames, 10,000,000	From Thames, 3,644,995	23 exclusive of waste.	173,637	170,550	1,174,089	—	—	—
		Walthamstow	From Lee, not restricted.	From Lee, 36,650,436		—	—	—	8	236	610,000,000
		Lee Bridge		From springs and wells 2,618,374		—	—	—	—	—	—
		Woodford Works	—			—	—	—	—	—	—
		Sunbury	—			—	—	—	—	—	—
		Hanworth	—	—		—	—	—	1	2	5,000,000
		Hornsey Wood	—	—		—	—	—	—	—	—
		High Beech	—	—		—	—	—	—	—	—
		Chingford (well)	—	—		—	—	—	—	—	—
		Buckhurst Hill (water tower).	—	—		—	—	—	—	—	—
		Waltham Abbey	—	—		—	—	—	—	—	—
		Total of East London Waterworks	10,000,000	42,913,805	—	173,637	170,550	1,174,089	9	238	615,000,000
Grand Junction Waterworks.	From the Thames at Hampton.	- - - - - -	24,500,000	18,659,092	12 to 15	57,775	43,609	392,870	—	—	—
		Hampton	—	—		—	—	—	3	12	51,000,000
		Kew	—	—		—	—	—	2	5	13,500,000
		Campden Hill	—	—		—	—	—	—	—	—
		Kilburn	—	—		—	—	—	—	—	—
		Hanger Hill, Ealing	—	—		—	—	—	—	—	—
		Ealing	—	—		—	—	—	—	—	—
		Total of Grand Junction Waterworks	24,500,000	18,659,092	—	57,775	43,609	392,870	5	17	64,500,000
Kent Waterworks.	From the Chalk Wells.	- - - -	Not restricted.	14,272,387	20	77,410	44,270	464,460			
		New Cross	—	—		—	—	—			
		Deptford	—	—		—	—	—			
		Woolwich Common	—	—		—	—	—			
		Plumstead Common	—	—		—	—	—			
		Greenwich Park	—	—		—	—	—			
		Chislehurst	—	—		—	—	—			
		Shortlands	—	—		—	—	—		None	
		Crayford	—	—		—	—	—			
		Dover Road, Shooters Hill	—	—		—	—	—			
		Farnborough	—	—		—	—	—			
		Dartford	—	—		—	—	—			
		West Wickham	—	—		—	—	—			
		Knockholt	—	—		—	—	—			
		Wilmington	—	—		—	—	—			
		Westerham	—	—		—	—	—			
		Total of Kent Waterworks	—	14,272,387	—	77,410	44,270	464,460	—	—	—
Lambeth Waterworks.	From the Thames at Molesey.	- - - - - -	24,500,000	19,591,097	25 exclusive of waste.	94,366	51,591	660,556	—	—	—
		Molesey	—	—		—	—	—	3	30	125,000,000
		Long Ditton	—	—		—	—	—	2	1	3,000,000
		Brixton	—	—		—	—	—	—	—	—
		Streatham	—	—		—	—	—	—	—	—
		Selhurst	—	—		—	—	—	—	—	—
		Rockhill	—	—		—	—	—	—	—	—
		Coombe	—	—		—	—	—	—	—	—
		Norwood	—	—		—	—	—	—	—	—
		Total of Lambeth Waterworks	24,500,000	19,591,097	—	94,366	51,591	660,565	5	31	128,000,000

of the Water Companies for the Month of May 1892.

Storage Filtered Water Covered Reservoirs.		Engine Power.		Number of Miles of Water-pipes.	Number of Miles of Water-pipes in the Metropolis.	Number of Miles of Streets with Water-pipes constantly charged within the Metropolis.	Number of Street Hydrants private Fire-cocks, and Fire-plugs erected within the Metropolis.	Greatest lift by Steam Power.	Head of Pressure in the District supplied.		Filters.		
											Filter Beds.		Maximum Depth of Sand and other Materials.
No.	Capacity. Gallons.	No.	Horse Power.						Greatest.	Least.	No.	Area in Acres.	
13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.
—	—	—	—	235 3/4 of which 129 1/2 are constantly charged.	208 1/4 of which 102 are constantly charged.	80	245 hydrants, about 4,987 fire-plugs.	Feet. 197	Feet. 145	Feet. 40	—	—	ft. in. Thames sand 4 6
—	—	—	—			—		—	—	—	—	—	Shells, &c. - 0 3
—	—	12	1,580			—		—	—	—	7	6 3/4	Gravel - 3 3
1	10,000,000	—	—			—		—	—	—	—	—	
2	1,000,000												
3	11,000,000	12	1,580	235 3/4	208 1/4	80	—	—	—	—	7	6 3/4	3' 0"
—	—	—	—	842 1/4	443	185 Many streets with 3, some with 5 lines of pipes.	2,202 public hydrants, 323 private hydrants, and about 12,000 fire-plugs.	Feet. —	Feet. 350	Feet. 40	—	—	ft. in. Sand - 2 0
—	—	1	200						—	—	—	—	Hoggin - 0 6
—	—	14	2,710						—	—	25	24 3/4	Coarse gravel 1 0
2	3,000,000	2	120						—	—	—	—	
—	—	2	150						—	—	—	—	
2	2,500,000	5	630						—	—	6	5	
1	5,000,000	—	—						—	—	—	—	
1	2,500,000	—	—						—	—	—	—	
—	—	3	97						—	—	—	—	
1	70,000	—	—						—	—	—	—	
—	—	1	200					500	—	—	—	—	
7	13,070,000	28	4,107	842 1/4	443	185	—	—	—	—	31	29 3/4	3' 6"
—	—	—	—	428 1/4	190	85 1/4	195 hydrants and 3,975 fire-plugs, of which 1,869 are attached to pipes constantly charged.	Feet. 235	Feet. 155	Feet. 30	—	—	Old Pattern. ft. in. Harwich sand 2 6
1	2,500,000	12	1,774					—	—	—	7	9 1/4	Hoggin 0 6; Fine gravel 0 9
1	2,500,000	7	1,106					—	—	—	8	8 1/2	Coarse gravel 0 9; Boulders - 1 0
3	18,000,000	3	532					—	—	—	—	—	New Pattern.
1	6,000,000	—	—					—	—	—	—	—	Sand - 2 0; Gravel - 0 6; Drains - 0 3
1	3,000,000 uncovered	—	—					—	—	—	—	—	
1	50,000,000 uncovered	—	—					—	—	—	—	—	
8	82,000,000	22	3,412	428 1/4	190	85 1/4	—	—	—	—	15	17 3/4	5' 6"
1	1,750,000	—	—	585 1/2	312	158 1/4	1,767 hydrants on public roads. 475 in Government Establishments. 180 Private. 1,430 fire-plugs.	Feet. 600	Feet. 620	Feet. 50			
—	—	—	—					—	—	—			
2	2,000,000	8	858					—	—	—			
1	1,500,000	—	—					—	—	—			
2	850,000	1	63					—	—	—			
1	1,125,000	—	—					—	—	—			
1	450,000	—	—					—	—	—			
—	—	2	93					—	—	—			
—	—	3	186					—	—	—	None		
1	300,000	2	47					—	—	—			
1	1,400,000	4	288					—	—	—			
1	370,000	—	—					—	—	—			
1	250,000	—	—					—	—	—			
1	500,000	—	—					—	—	—			
—	—	1	130					—	—	—			
1	60,000	—	—					—	—	—			
14	10,555,000	21	1,665	585 1/2	312	158 1/4	—	—	—	—	—	—	—
—	—	—	—	685 3/4 of which 450 are constantly charged.	414 of which 312 are constantly charged.	171 Many streets with 2 and 3 and some with 6 lines of pipes.	2,033 Public hydrants. 337 hydrants for street watering. 159 Private hydrants & about 11,050 fire-plugs.	Feet. 380	Feet. 380 upon pumping mains. 150 upon serving mains.	Feet. 20	—	—	ft. in. Thames sand 3 0
—	—	2	100					—		—	—	—	Shells, &c. - 1 0
—	—	13	2,220					—		—	10	9 1/2	Coarse gravel 3 0
2	12,000,000	12	930					—		—	—	—	
2	7,500,000	—	—					—		—	—	—	
1	2,500,000	—	—					—		—	—	—	
1	615,000	—	—					—		—	—	—	
1	1,150,000	—	—					—		—	—	—	
1	5,000,000	—	—					—		—	—	—	
8	28,765,000	27	3,250	685 3/4	414	171	—	—	—	—	10	9 1/2	7' 0"

Statistics of the Metropolitan Water Supply and Works

Name of the Company	Intake.	Situation of Works.	*Total Volume which may be drawn daily. Gallons.	Average Daily Supply during the Month. Gallons.	Approximate per-centage delivered for other than domestic purposes.	Number of Supplies to Houses, &c. returned.	Number of Houses on constant Supply.	Estimated Population supplied within the Districts of the Water Companies	Subsiding and Storage Reservoirs for Unfiltered Water. No.	Area in Acres.	Available Capacity. Gallons.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
New River	From Chadwell Spring the River Lee, and thirteen Chalk Wells.	- - - -	Not restricted	33,049,786 filtered, of which 12,216,588 were drawn from springs and wells, and 20,833,198 from the Lee; and 2,942,214 unfiltered, of which 287,417 were drawn from Hampstead and Highgate Ponds; 1,052,795 from springs and wells, and 1,602,002 from the Lee.	25 exclusive of waste.	155,357	73,555	1,165,000	—	—	—
		New River Head	—			—	—	—	1	3/4	700,000
		Claremont Square	—			—	—	—	—	—	—
		Stoke Newington	—			—	—	—	2	42 1/2	90,000,000
		Hornsey	—			—	—	—	2	8	8,500,000
		Campsbourne (well)	—			—	—	—	—	—	—
		Maiden Lane	—			—	—	—	—	—	—
		Hornsey Lane	—			—	—	—	—	—	—
		Highgate	—			—	—	—	} 12	28 3/4	29,000,000
		Hampstead	—			—	—	—			
		Camden Park Road	—			—	—	—	1	1	900,000
		Amwell End (well)	—			—	—	—	—	—	—
		Amwell Hill (well)	—			—	—	—	—	—	—
		Amwell Marsh (well)	—			—	—	—	—	—	—
		Hoddesdon (well)	—			—	—	—	—	—	—
		Broxbourne (well)	—			—	—	—	—	—	—
		Turnford (well)	—			—	—	—	—	—	—
		Cheshunt (well and reservoir)	—			—	—	—	2	18 1/2	39,000,000
		Tottenham	—			—	—	—	—	—	—
		Southgate	—			—	—	—	—	—	—
		Botstile (well)	—			—	—	—	—	—	—
		Crouch Hill	—			—	—	—	—	—	—
		Broad Mead (well)	—			—	—	—	—	—	—
		Rye Common (well)	—			—	—	—	—	—	—
		Hoe Lane (well)	—			—	—	—	—	—	—
		Highfield, Edmonton (well)	—			—	—	—	—	—	—
		Bourne Hill	—			—	—	—	—	—	—
		Bush Hill	—			—	—	—	—	—	—
		Total of New River Company	—	35,992,000	—	155,357	73,555	1,165,000	20	99 1/2	168,100,000
Southwark and Vauxhall Waterworks.	From the Thames at Hampton.	- - - -	24,500,000	28,400,384	15 to 20 exclusive of waste.	114,218	93,196	848,639	—	—	—
		Hampton	—	—		—	—	—	3	5 1/2	20,000,000
		Battersea	—	—		—	—	—	3	12	46,000,000
		Nunhead	—	—		—	—	—	—	—	—
		Total of Southwark and Vauxhall Waterworks	24,500,000	28,400,384	—	114,218	93,196	848,639	6	17 1/2	66,000,000
West Middlesex Waterworks.	From the Thames at Hampton.	- - - -	24,500,000	18,023,487	14 exclusive of waste.	75,523	34,655	585,303	—	—	—
		Hampton	—	—		—	—	—	—	—	—
		Hammersmith	—	—		—	—	—	—	—	—
		Barnes	—	—		—	—	—	4	37	117,500,000
		Campden Hill	—	—		—	—	—	—	—	—
		Barrow Hill	—	—		—	—	—	—	—	—
		Finchley Road	—	—		—	—	—	—	—	—
		Willesden	—	—		—	—	—	—	—	—
		Total of West Middlesex Waterworks	24,500,000	18,023,487	—	75,523	34,655	585,303	4	37	117,500,000
	From Thames		130,000,000	98,925,329							
	Other Sources		Not restricted	89,533,197							
Grand Total for the Metropolis			—	188,458,526	—	784,643	822,296	6,579,111	53	480	1,299,100,000

* In December 1886 the licences of the several Companies to draw water from the Thames were widened by agreement with the Conservators. The additional quantity of water to be taken daily by each of the Companies under the Agreement was, in the case of the Grand Junction, Lambeth, Southwark and Vauxhall, and West Middlesex, 4,500,000 gallons, and in the case of the Chelsea Company, 2,000,000 gallons.

of the Water Companies for the Month of May 1892.

Storage Filtered Water Covered Reservoirs		Engine Power.		Number of Miles of Water-pipes.	Number of Miles of Water-pipes in the Metropolis.	Number of Miles of Streets with Water-pipes constantly charged within the Metropolis	Number of Street Hydrants private Fire-cocks, and Fire-plugs erected within the Metropolis.	Greatest lift by Steam Power.	Pressure in the District supplied.		Filters. Filter Beds.		Filters. Maximum Depth of Sand and other Materials.
No.	Capacity. Gallons.	No.	Horse Power.						Greatest.	Least.	No.	Area in Acres.	
13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.
—	—	—	—	821 of which 494 are constantly charged.	765 of which 442 are constantly charged.	308	3,989 Public hydrants. 441 hydrants for street watering. 3,473 Private hydrants and about 12,500 fire-plugs.	Feet. 590	Feet. 260	Feet. 40	—	—	ft. in. Sand - 2 3
—	—	2	200					—	—	—	3	2 1/4	Gravel - 3 4
1	3,500,000	—	—					—	—	—	—	—	Increasing in coarseness towards bottom.
—	—	8	1,350					—	—	—	9	9	
—	—	4	440					—	—	—	8	5 1/4	
—	—	2	190					—	—	—	—	—	
2	15,000,000	—	—					—	—	—	—	—	
1	3,000,000	2	135					—	—	—	—	—	
{ 1	1,000,000	—	—					—	—	—	—	—	
{ 1	500,000	—	—					—	—	—	—	—	
—	—	—	—					—	—	—	—	—	
—	—	1	50					—	—	—	—	—	
—	—	2	75					—	—	—	—	—	
—	—	2	70					—	—	—	—	—	
—	—	1	50					—	—	—	—	—	
—	—	3	180					—	—	—	—	—	
—	—	2	150					—	—	—	—	—	
—	—	1	20					—	—	—	—	—	
—	—	2	125					—	—	—	—	—	
1	1,000,000	—	—					—	—	—	—	—	
—	—	2	24					—	—	—	—	—	
2	12,000,000	—	—					—	—	—	—	—	
—	—	1	16					—	—	—	—	—	
—	—	2	200					—	—	—	—	—	
—	—	2	170					—	—	—	—	—	
—	—	3	210					—	—	—	—	—	
1	1,500,000	—	—					—	—	—	—	—	
1	40,000	—	—					—	—	—	—	—	
11	37,540,000	42	3,655	821	766	308	—	—	—	—	20	16 1/2	5 1′
—	—	—	—	782	600	160	2,550 hydrants and 11,700 fire-plugs.	Feet. 360	Feet. 170	Feet. 20	—	—	ft. in. Harwich sand 3 0
—	—	8	1,900					—	—	—	3	3 1/4	Hoggin - 1 0
—	—	6	1,200					—	—	—	9	11 1/4	Fine gravel 0 9
4	18,000,000	2	100					—	—	—	—	—	Coarse gravel 0 9
4	18,000,000	16	3,200	782	600	160	—	—	—	—	12	14 1/2	5′ 6″
—	—	—	—	440 1/2 of which 236 1/2 are constantly charged.	328 of which 177 1/4 are constantly charged.	120 1/2	324 hydrants and about 5,000 fire-plugs.	Feet. —	Feet. —	Feet. —	—	—	ft. in. Harwich sand 2 3
—	—	4	560					—	—	—	—	—	Barnes sand 1 0
—	—	9	1,485					195	190	130	—	—	Gravel - 2 3
—	—	1	6					—	—	—	12	16	Screened to different sizes and arranged in layers.
1	3,672,000	—	—					—	—	—	—	—	
1	4,750,000	3	210					150	—	—	—	—	
1	2,500,000	—	—					—	—	—	—	—	
1	2,500,000	—	—					—	—	—	—	—	
4	13,422,000	17	2,261	440 1/2	328	120 1/2	—	—	—	—	12	15	5′ 6′
59	214,352,000	185	23,130	4821	3261 1/4	1,268	18,693 hydrants.	—	—	—	107	109 3/4	—

A. de C. Scott,
Water Examiner, Metropolis Water Act, 1871.
40, *Chancery Lane, W.C.*,
2nd July 1892.

To the Secretary,
Local Government Board.

APPENDIX.

Report of the Results of Analyses of the Metropolitan Water Supply undertaken during May 1892 by Dr. E. Frankland, F.R.S., on behalf of the Local Government Board.

Water-analysis Laboratory,
The Yews, Reigate,
6th June 1892.

Sir,

I have to report to you the results of the chemical analysis and of the physical and bacteriological examination of the waters supplied to the inner, and portions of the outer, circle of the Metropolis during the month of May.

At the request of the Associated Metropolitan Water Companies, I have extended these monthly examinations to (*a*) the chemical and bacteriological condition of the raw river waters at the intakes of the various Companies, and (*b*) to the bacteriology of the water as it issues from the filter beds of each Company, and before it is pumped into the distributing mains.

I append, also, the results obtained in the analyses of the waters supplied to Birmingham and Glasgow by their respective Corporations. These analyses were made by Dr. Hill of Birmingham and Dr. Mills of Glasgow.

Taking the average amount of organic impurity contained in a given volume of the Kent Company's water during the nine years ending December 1876 as unity, the proportional amount contained in an equal volume of water supplied by each of the Metropolitan Water Companies and by the Tottenham Local Board of Health was:—Kent 0·6, New River and Colne Valley 1·1, Tottenham and East London (deep-well) 1·3, East London (river supply) 1·9, Chelsea, 2·1, West Middlesex and Grand Junction 2·2, Lambeth 2·3, and Southwark 2·5. The untreated river waters gave the following numbers:—New River cut 1·5, River Lea at East London Company's intake 2·9, and Thames at Hampton 3·4.

The water abstracted from the Thames by the Chelsea, West Middlesex, Southwark, Grand Junction, and Lambeth Companies was again, for river water, of a high degree of organic purity, being even superior, in this respect, to the samples drawn in April. It consisted, in fact, chiefly of spring water discharged from the chalk and oolite. It was efficiently filtered before delivery.

The water taken chiefly from the Lea by the New River Company again ranked with the deep-well waters in respect of organic purity, whilst that supplied from the same source, but lower down the stream, by the East London Company was superior to the best of the Thames waters. Both supplies were efficiently filtered.

The deep-well waters of the Kent, Colne Valley, and East London Companies, and of the Tottenham Local Board of Health, were of excellent quality for dietetic use, that of the Kent Company being especially distinguished for its very high degree of organic purity. The Colne Valley Company's water, having been softened before delivery, was rendered suitable for washing. All these waters were clear and bright without filtration.

Seen through a stratum two feet deep, the Kent, Colne Valley, Tottenham, and East London (deep-well) waters were clear and colourless, the New River clear and nearly colourless, whilst the remaining waters were clear and very pale yellow. The crude river waters presented the following appearances:—New River cut turbid and very pale yellow, the Lea at the East London Company's intake and the Thames at Hampton turbid and pale yellow.

The bacteriological examination of the waters as they left the filters of the various Companies, by Dr. Koch's process of gelatine plate-culture gave the following results. One cubic centimetre of each water collected on May 20th and 21st developed the following numbers of colonies of microbes:—West Middlesex and Lambeth 4, Southwark 8, New River and East London 10, Chelsea 12, and Grand Junction 24. Of the untreated river waters, one cubic centimetre of the water from the New River cut developed 158, the Thames at Hampton 631, and the Lea at the intake of the East London Company 4,526 colonies of microbes.

Dr. Hill, F.I.C., the Medical Officer of Health for Birmingham, reports that the water supplied to that city was "clear and of good colour, and the organic elements were less than they have been for a year."

Dr. Mills, F.R.S., of the Glasgow and West of Scotland Technical College, reports that the water supplied to that city from Loch Katrine was "light brown in colour and contained a little suspended matter."

I am, Sir,
Your obedient Servant,
(Signed) E. Frankland.

To the Secretary,
Local Government Board,
Whitehall, S.W.

Table of the Results of the Chemical Analyses referred to in the foregoing Report.

All the numbers in columns **4, 5, 6, 7, 8, 9, 10,** and **11** relate to **100,000** parts of the water.

The Table is to be read thus:—The Chelsea Company's water, collected on the 23rd May at the Horse Guards cab rank, had a temperature of **13°·2** C., **100,000** lbs. of it contained **24·54** lbs. of solid matter: the organic substances, constituting a portion of this matter, contained **·110** lb. of carbon and **·014** lb. of nitrogen. The above quantity of water also contained *no* ammonia, and **·163** lb. of nitrogen in the form of nitrates and nitrites, whilst the total amount of *combined* nitrogen in every form was **·177** lb. The above weight of water also contained **1·8** lb. of chlorine, and **17·4** lbs. of carbonate of lime, or an equivalent quantity of other hardening or soap-destroying ingredients.

The numbers in the analytical Table can be converted into grains per imperial gallon by multiplying them by **7**, and then moving the decimal point one place to the left. The same operation transforms the hardness in the Table into degrees of hardness on Clark's scale.

Results of Analysis expressed in Parts per 100,000.

	Companies or Local Authorities.	Date and Place of Collection.	Temperature in Centigrade Degrees.	Total Solid Matter.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen, as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Total Hardness.
Inner Circle.	THAMES. (Unfiltered water)	May 20th; Grand Junction Co's. intake at Hampton.	**14·8**	**28·16**	**·180**	**·024**	**·016**	**·153**	**·190**	**1·8**	**18·9**
Inner Circle.	Chelsea	May 23rd, Cab Rank, Horse Guards, Whitehall.	**13·2**	**24·54**	**·110**	**·014**	**0**	**·163**	**·177**	**1·8**	**17·4**
Inner Circle.	West Middlesex	May 23rd, Cab Rank, Riding House Street.	**12·0**	**24·04**	**·113**	**·015**	**0**	**·154**	**·169**	**1·8**	**17·7**
Inner Circle.	Southwark	May 23rd, Cab Rank, Bricklayers' Arms, Old Kent Road.	**14 3**	**26·34**	**·126**	**·020**	**0**	**·161**	**·180**	**1·8**	**19·4**
Inner Circle.	Grand Junction	May 23rd, Cab Rank, Portman St., Oxford Street.	**15·7**	**25·80**	**·115**	**·014**	**0**	**·168**	**·182**	**1·8**	**18·9**
Inner Circle.	Lambeth	May 23rd, Cab Rank, St. George's Road, Southwark.	**14·4**	**27·28**	**·120**	**·016**	**0**	**·235**	**·251**	**1·9**	**19·4**
Inner Circle.	LEA. (Unfiltered water)	May 21st, New River Cut at Green Lanes.	**14·5**	**27·28**	**·076**	**·013**	**.004**	**·218**	**·234**	**1·7**	**20·0**
Inner Circle.	New River	May 23rd, Cab Rank, Tottenham Court Road.	**14·2**	**26·50**	**·050**	**·012**	**0**	**·195**	**·207**	**1·9**	**18·9**
Inner Circle.	(Unfiltered water)	May 21st, East London Co's. intake at Angel Road	**15·2**	**29·30**	**·148**	**·022**	**·012**	**·222**	**·254**	**1·9**	**21·5**
Inner Circle.	East London	May 23rd, Fire Brigade Station, Commercial Road, E.	**13·7**	**28·90**	**·093**	**·019**	**0**	**·271**	**·290**	**2·0**	**20·0**
Inner Circle.	DEEP WELLS. Kent‡	May 23rd, Mill Lane, Deptford.	**12·4**	**41·92**	**·021**	**·012**	**0**	**·478**	**·490**	**2·5**	**28·7**
Outer Circle.	Colne Valley	May 23rd, Bushey.	—	**17·90**	**·048**	**·016**	**0**	**·370**	**·386**	**2·1**	**7·9**
Outer Circle.	Tottenham	May 21st, Tottenham.	—	**42·24**	**·055**	**·019**	**·045**	**·036**	**·092**	**3·1**	**23·6**
Outer Circle.	East London	May 24th, Waltham Abbey Well.	—	**27·46**	**·067**	**·012**	**0**	trace!	**·012**	**2·1**	**17·7**
	Corporation of Birmingham*	May 9th, Rear of 23 Parade.	**10·5**	**28·58**	**·099**	**·015**	**0**	**·308**	**·323**	**2·0**	**20·7**
	Corporation of Glasgow†	May 16th, Loch Katrine Water.	**8·8**	**2·5**	**·203**	**·031**	**0**	**·0035**	**·0345**	**·72**	**·63**
	Column **1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**

* Analysed by Dr. Alfred Hill, F.I.C., Medical Officer of Health and Analyst to the City.
† Analysed by Dr. E. J. Mills, F.R.S., of the Glasgow and West of Scotland Technical College.
‡ NOTE.—The organic carbon in the Kent Water Co's. well at Orpington was erroneously printed as ·118 instead of ·018 in the water report for last month.

The subjoined communication, together with the succeeding three tables, have been received by the Metropolitan Water Examiner from the Chemists carrying out analyses on behalf of the Directors of the Water Companies deriving their supply from the Thames and the Lea :—

SIR, London, June 11th, 1892.

WE submit herewith, at the request of the Directors, the results of our analyses of the 182 samples of water collected by us during the past month, at the several places and on the several days indicated, from the mains of the seven London Water Companies taking their supply from the Thames and Lea.

In Table I. we have recorded the analyses in detail of samples, one taken daily, from May 1st to May 31st inclusive. The purity of the water, in respect to organic matter, has been determined by the Oxygen and Combustion processes; and the results of our analyses by these methods are stated in Columns XIV. to XVIII.

We have recorded in Table II. the tint of the several samples of water, as determined by the colour-meter described in a previous report.

In Table III. we have recorded the oxygen required to oxidise the organic matter in all the samples submitted to analysis.

Of the 182 samples examined, three were found to be very slightly turbid; the remainder being clear, bright, and well filtered.

The character of the water supply to the Metropolis during the month of May was not found to differ appreciably from that manifested during the two or three months preceding. The proportion of organic matter present in the water—noticeably low throughout—was found to be just a little higher in the March supply than in that of February, but lower again in that of April, and still lower in that of the past month; this statement being applicable both to the Thames-derived and the Lea-derived supplies.

The following Table shows the smallness of the proportion of organic matter present in the Thames-derived supply, taken for illustration, and the successive but not important decrease in its proportion during the past three months. With the coming on, however, of any considerable rainfall, a corresponding unimportant increase in the proportion may be anticipated. The maximum proportion of organic carbon met with in any one of the 536 samples examined during the past three months, or 0·188 part in 100,000 parts of the water, corresponds as nearly as may be to a little over three-tenths of a grain of organic matter per gallon :—

——	Ratio of Brown to Blue Tint.	Oxygen required for Oxidation.	Organic Carbon per 100,000.	Organic Carbon per 100,000.
	Means.	Means.	Means.	Maxima.
March - - -	8·6 : 20	·043	·144	·188
April - - -	5·6 : 20	·033	·125	·147
May - - - -	4·7 : 20	·029	·119	·143

We are, Sir,
Your obedient Servants,
WILLIAM CROOKES.
WILLIAM ODLING.

TABLE I.

Results of the Analysis of Daily Samples of the Water as supplied to the Metropolis, for the Month ending May 31st, 1892.

The results are stated in Grains per Imperial Gallon of 70,000 grains, except the Organic Carbon and Nitrogen, which are expressed both in Grains per Gallon and in parts per 100,000.

I. No.	II. Date of Collection.	III. Time of Collection.	IV. Company from the Mains of which the Sample was drawn.	V. Place where the Sample was drawn.	VI. Appearance.*	VII. Matters in Suspension.	VIII. Ammonia.	IX. Chlorine.	X. Common Salt. (NaCl).	XI. Nitrogen.	XII. Nitric Acid. (HNO_3).	XIII. Initial Hardness.	XIV. Oxygen required to Oxidise the Organic Matter. †	XV. Organic Carbon.	XVI. Organic Nitrogen.	XVII. Organic Carbon.	XVIII. Organic Nitrogen.
	1892.					Grains.	Grains.	Grains. =	Grains.	Grains. =	Grains.	Degrees.	Grains.	Grains per Gallon.		Parts per 100,000.	
3501	May 6	5.30 p.m.	New River Co.	Tottenham Court Road	Clear	None	0·000	1·368 =	2·242	0·167 =	0·751	16·10°	0·016	0·040	0·010	0·057	0·015
3508	" 14	6.25 "	New River Co.	Tottenham Court Road	Clear	None	0·000	1·296 =	2·124	0·188 =	0·846	13·80°	0·007	0·033	0·012	0·048	0·017
3515	" 23	5.0 "	New River Co.	Tottenham Court Road	Clear	None	0·000	1·368 =	2·242	0·167 =	0·751	15·05°	0·012	0·048	0·011	0·069	0·016
3522	" 31	5.20 "	New River Co.	Tottenham Court Road	Clear	None	0·000	1·368 =	2·242	0·177 =	0·796	15·05°	0·008	0·039	0·011	0·056	0·016
				Averages	—	—	0·000	1·350 =	2·212	0·175 =	0·788	15·00°	0·011	0·040	0·011	0·057	0·016
3502	" 7	8.30 "	East London Co.	Cambridge Road	Clear	None	0·000	1·512 =	2·478	0·177 =	0·796	16·95°	0·020	0·071	0·016	0·101	0·023
3509	" 16	8.20 "	East London Co.	Cambridge Road	Clear	None	0·000	1·512 =	2·478	0·177 =	0·796	15·20°	0·031	0·077	0·021	0·110	0·030
3516	" 24	7.30 "	East London Co.	Cambridge Road	Clear	None	0·000	1·512 =	2·478	0·156 =	0·702	15·20°	0·028	0·094	0·021	0·134	0·030
				Averages	—	—	0·000	1·512 =	2·478	0·170 =	0·765	15·78°	0·026	0·081	0·019	0·115	0·027
3503	" 9	7.30 "	Chelsea Co.	Horse Guards	Clear	None	0·000	1·296 =	2·124	0·156 =	0·702	15·05°	0·023	0·070	0·019	0·100	0·027
3510	" 17	6.30 "	Chelsea Co.	Horse Guards	Clear	None	0·000	1·296 =	2·124	0·135 =	0·607	15·05°	0·023	0·069	0·016	0·099	0·023
3517	" 25	6.25 "	Chelsea Co.	Horse Guards	Clear	None	0·000	1·296 =	2·124	0·156 =	0·702	14·84°	0·028	0·098	0·021	0·140	0·030
				Averages	—	—	0·000	1·296 =	2·124	0·149 =	0·670	14·98°	0·025	0·079	0·019	0·113	0·027
3497	" 2	6.0 "	West Middlesex Co.	Portland Road	Clear	None	0·000	1·296 =	2·124	0·156 =	0·702	16·10°	0·030	0·091	0·017	0·130	0·024
3504	" 10	6.0 "	West Middlesex Co.	Portland Road	Clear	None	0·000	1·296 =	2·124	0·146 =	0·657	15·68°	0·023	0·087	0·020	0·124	0·029
3511	" 18	6.0 "	West Middlesex Co.	Portland Road	Clear	None	0·000	1·296 =	2·124	0·146 =	0·657	15·47°	0·027	0·075	0·014	0·108	0·020
3518	" 26	6.15 "	West Middlesex Co.	Portland Road	Clear	None	0·000	1·296 =	2·124	0·135 =	0·607	14·84°	0·028	0·089	0·018	0·128	0·026
				Averages	—	—	0·000	1·296 =	2·124	0·146 =	0·656	15·52°	0·027	0·085	0·017	0·122	0·025
3498	" 3	7.10 "	Lambeth Co.	St. George's Road, Southwark	Clear	None	0·000	1·368 =	2·242	0·146 =	0·657	14·84°	0·030	0·085	0·019	0·122	0·028
3505	" 11	7.20 "	Lambeth Co.	St. George's Road, Southwark	Clear	None	0·000	1·296 =	2·124	0·177 =	0·796	15·66°	0·024	0·084	0·019	0·120	0·028
3512	" 19	7.20 "	Lambeth Co.	St. George's Road, Southwark	Clear	None	0·000	1·296 =	2·124	0·167 =	0·751	14·84°	0·035	0·072	0·028	0·104	0·033
3519	" 27	6.45 "	Lambeth Co.	St. George's Road, Southwark	Clear	None	0·000	1·512 =	2·478	0·177 =	0·796	14·84°	0·032	0·089	0·016	0·128	0·023
				Averages	—	—	0·000	1·368 =	2·242	0·167 =	0·750	15·05°	0·030	0·082	0·019	0·118	0·028
3499	" 4	6.20 "	Grand Junction Co.	Uxbridge Road	Clear	None	0·000	1·296 =	2·124	0·167 =	0·751	14·84°	0·030	0·080	0·018	0·114	0·026
3506	" 12	6.30 "	Grand Junction Co.	Uxbridge Road	Clear	None	0·000	1·296 =	2·124	0·156 =	0·702	14·84°	0·024	0·100	0·024	0·143	0·035
3513	" 20	7.5 "	Grand Junction Co.	Uxbridge Road	Clear	None	0·000	1·368 =	2·242	0·146 =	0·657	14·84°	0·031	0·064	0·015	0·091	0·021
3520	" 28	6.0 "	Grand Junction Co.	Uxbridge Road	Clear	None	0·000	1·368 =	2·242	0·135 =	0·607	14·84°	0·032	0·085	0·020	0·121	0·029
				Averages	--	—	0·000	1·332 =	2·183	0·151 =	0·679	14·84°	0·029	0·082	0·019	0·117	0·028
3500	" 5	7.15 "	Southwark and Vauxhall Co.	St. George's Church, Borough	Clear	None	0·000	1·296 =	2·124	0·156 =	0·702	15·68°	0·030	0·094	0·021	0·135	0·030
3507	" 13	8.5 "	Southwark and Vauxhall Co.	St. George's Church, Borough	Clear	None	0·000	1·296 =	2·124	0·156 =	0·702	14·42°	0·027	0·070	0·022	0·100	0·031
3514	" 21	7.30 "	Southwark and Vauxhall Co.	St. George's Church, Borough	Clear	None	0·000	1·296 =	2·124	0·135 =	0·607	15·05°	0·039	0·100	0·019	0·143	0·027
3521	" 30	7.0 "	Southwark and Vauxhall Co.	St. George's Church, Borough	Clear	None	0·000	1·296 =	2·124	0·135 =	0·607	14·84°	0·040	0·094	0·023	0·134	0·033
				Averages	—	—	0·000	1·296 =	2·124	0·145 =	0·654	15·00°	0·034	0·089	0·021	0·128	0·030

* See Table II.

† The amount of oxygen is determined by a standard solution of potassic permanganate acting in the cold for three hours.

TABLE II.

Showing the Appearance and Condition of the Water as regards Turbidity, and the Colour determined by Standard Tints in a Two-Foot Tube, of the Water supplied to the Metropolis, from the Mains of the several Companies, for the Month ending May 31st, 1892.

No.	Date of Collection.	New River Company.		East London Company.		Chelsea Company.		West Middlesex Company.		Lambeth Company.		Grand Junction Company.		Southwark and Vauxhall Company.	
		Appearance.	Colour.	Appearance.	Colour.	Appearance.	Colour.	Appearance.	Colour.	Appearance.	Colour.	Appearance.	Colour.	Appearance.	Colour.
	1892.		Brown : Blue		Brown : Blue		Brown : Blue		Brown : Blue		Brown : Blue		Brown : Blue		Brown : Blue
3497	May 2 -	C.	1 : 20	C.	4 : 20	C.	4 : 20	C.	4 : 20	C.	5 : 20	C.	4 : 20	C.	4 : 20
3498	" 3 -	C.	1 : 20	C.	3 : 20	C.	3 : 20	C.	4 : 20	C.	5 : 20	C.	4 : 20	C.	5 : 20
3499	" 4 -	C.	1 : 20	C.	4 : 20	C.	4 : 20	C.	5 : 20	C.	5 : 20	C.	5 : 20	C.	5 : 20
3500	" 5 -	C.	1 : 20	C.	3 : 20	C.	4 : 20	C.	3 : 20	C.	4 : 20	C.	4 : 20	C.	5 : 20
3501	" 6 -	C.	2 : 20	C.	3 : 20	C.	3 : 20	C.	4 : 20	C.	5 : 20	C.	5 : 20	C.	7 : 20
3502	" 7 -	C.	2 : 20	C.	4 : 20	C.	4 : 20	C.	3 : 20	C.	6 : 20	C.	5 : 20	C.	6 : 20
3503	" 9 -	C.	1 : 20	C.	3 : 20	C.	3 : 20	C.	4 : 20	C.	8 : 20	C.	4 : 20	C.	5 : 20
3504	" 10 -	C.	1 : 20	C.	4 : 20	C.	3 : 20	C.	3 : 20	C.	3 : 20	C.	4 : 20	C.	4 : 20
3505	" 11 -	C.	1 : 20	C.	3 : 20	C.	3 : 20	C.	3 : 20	C.	8 : 20	C.	5 : 20	C.	4 : 20
3506	" 12 -	C.	1 : 20	C.	3 : 20	C.	3 : 20	C.	3 : 20	C.	8 : 20	C.	3 : 20	C.	3 : 20
3507	" 13 -	C.	1 : 20	C.	3 : 20	C.	3 : 20	C.	3 : 20	C.	3 : 20	C.	4 : 20	C.	4 : 20
3508	" 14 -	C.	1 : 20	V.S.T.	11 : 20	C.	3 : 20	C.	4 : 20	C.	4 : 20	C.	4 : 20	C.	4 : 20
3509	" 16 -	C.	1 : 20	C.	3 : 20	C.	3 : 20	C.	4 : 20	C.	6 : 20	C.	7 : 20	C.	7 : 20
3510	" 17 -	C.	2 : 20	C.	6 : 20	C.	4 : 20	C.	5 : 20	C.	8 : 20	C.	7 : 20	V.S.T.	10 : 20
3511	" 18 -	C.	2 : 20	C.	5 : 20	C.	2 : 20	C.	4 : 20	C.	4 : 20	C.	6 : 20	C.	7 : 20
3512	" 19 -	C.	1 : 20	C.	4 : 20	C.	2 : 20	C.	4 : 20	C.	4 : 20	C.	5 : 20	C.	6 : 20
3513	" 20 -	C.	2 : 20	C.	6 : 20	C.	4 : 20	C.	6 : 20	C.	5 : 20	C.	6 : 20	C.	6 : 20
3514	" 21 -	C.	2 : 20	C.	5 : 20	C.	4 : 20	C.	5 : 20	C.	5 : 20	C.	7 : 20	C.	6 : 20
3515	" 23 -	C.	1 : 20	C.	4 : 20	C.	4 : 20	C.	4 : 20	C.	5 : 20	C.	6 : 20	C.	7 : 20
3516	" 24 -	C.	1 : 20	C.	4 : 20	C.	3 : 20	C.	4 : 20	C.	5 : 20	C.	4 : 20	C.	6 : 20
3517	" 25 -	C.	1 : 20	C.	4 : 20	C.	3 : 20	C.	8 : 20	C.	5 : 20	C.	4 : 20	C.	4 : 20
3518	" 26 -	C.	1 : 20	C.	4 : 20	C.	4 : 20	C.	3 : 20	C.	8 : 20	C.	5 : 20	C.	7 : 20
3519	" 27 -	C.	2 : 20	C.	6 : 20	C.	3 : 20	C.	5 : 20	C.	6 : 20	C.	6 : 20	C.	9 : 20
3520	" 28 -	C.	2 : 20	C.	5 : 20	C.	3 : 20	C.	6 : 20	C.	7 : 20	C.	8 : 20	C.	8 : 20
3521	" 30 -	C.	2 : 20	V.S.T.	6 : 20	C.	4 : 20	C.	4 : 20	C.	5 : 20	C.	7 : 20	C.	10 : 20
3529	" 31 -	C.	1 : 20	C.	5 : 20	C.	3 : 20	C.	4 : 20	C.	10 : 20	C.	5 : 20	C.	7 : 20
	Average -	—	1·3 : 20	—	4·3 : 20	—	3·4 : 20	—	3·9 : 20	—	5·0 : 20	—	5·1 : 20	—	6·0 : 20

Degrees of Turbidity.

Note.— C. = Clear.
V. S. T. = Very slightly turbid.
S. T. = Slightly turbid.
T. = Turbid.

Colour Test.

Note.—The ratios show the proportions of Brown to Blue in the water; the figures representing millimetres in thickness of the respective standard solutions. Thus 10 : 20 would express a colour composed of 10 millimetres of Brown solution superposed on 20 millimetres of Blue solution.

TABLE III.

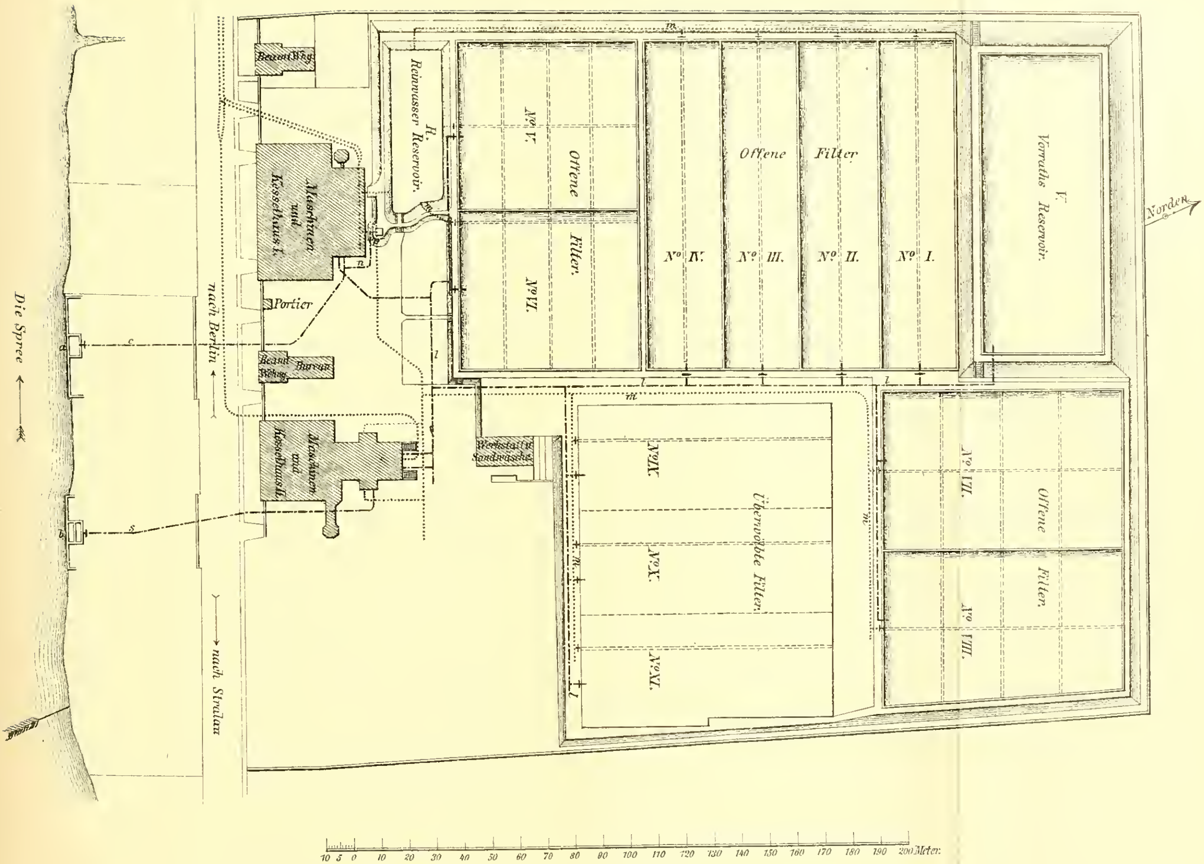
Showing the Quantity of Oxygen in Grains per Gallon required to Oxidise the Organic Matter, in Daily Samples of the Water as supplied to the Metropolis, from the Mains of the Companies, during the Month ending May 31st, 1892.

No.	Date of Collection.	New River Company. Oxygen required by Organic Matter.	East London Company. Oxygen required by Organic Matter.	Chelsea Company. Oxygen required by Organic Matter.	West Middlesex Company. Oxygen required by Organic Matter.	Lambeth Company. Oxygen required by Organic Matter.	Grand Junction Company. Oxygen required by Organic Matter.	Southwark and Vauxhall Company. Oxygen required by Organic Matter.
	1892.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.
3497	May 2	0·011	0·033	0·030	0·030	0·033	0·033	0·033
3498	„ 3	0·011	0·030	0·030	0·030	0·030	0·026	0·026
3499	„ 4	0·011	0·023	0·026	0·026	0·030	0·030	0·030
3500	„ 5	0·015	0·023	0·026	0·026	0·030	0·026	0·030
3501	„ 6	0·016	0·024	0·028	0·028	0·028	0·032	0·032
3502	„ 7	0·012	0·020	0·024	0·024	0·028	0·028	0·028
3503	„ 9	0·008	0·023	0·023	0·019	0·031	0·027	0·035
3504	„ 10	0·008	0·023	0·023	0·023	0·027	0·027	0·035
3505	„ 11	0·004	0·020	0·024	0·024	0·024	0·028	0·028
3506	„ 12	0·004	0·024	0·024	0·024	0·024	0·024	0·024
3507	„ 13	0·007	0·023	0·019	0·023	0·023	0·035	0·027
3508	„ 14	0·007	0·027	0·027	0·027	0·027	0·031	0·027
3509	„ 16	0·015	0·031	0·019	0·039	0·039	0·039	0·039
3510	„ 17	0·015	0·029	0·023	0·039	0·040	0·039	0·039
3511	„ 18	0·011	0·023	0·011	0·027	0·031	0·035	0·035
3512	„ 19	0·011	0·019	0·011	0·027	0·035	0·031	0·035
3513	„ 20	0·012	0·023	0·027	0·027	0·031	0·031	0·035
3514	„ 21	0·011	0·027	0·035	0·027	0·031	0·031	0·039
3515	„ 23	0·012	0·028	0·032	0·036	0·040	0·040	0·036
3516	„ 24	0·016	0·028	0·032	0·036	0·040	0·040	0·040
3517	„ 25	0·008	0·028	0·028	0·024	0·036	0·032	0·032
3518	„ 26	0·008	0·024	0·028	0·028	0·036	0·028	0·032
3519	„ 27	0·012	0·024	0·024	0·028	0·032	0·032	0·032
3520	„ 28	0·012	0·024	0·024	0·028	0·032	0·032	0·032
3521	„ 30	0·012	0·020	0·024	0·024	0·032	0·036	0·040
3522	„ 31	0·008	0·020	0·020	0·024	0·032	0·032	0·036
	Average	0·010	0·024	0·024	0·027	0·032	0·032	0·033

Situation and Number of the Chalk Wells of the Kent Company.

Place.	No.
Deptford	3
Plumstead	1
Crayford	3
Shortlands	2
Farnborough	2
Wilmington	1
Total	12

The water supplied by this Company is taken from Chalk Wells, and is therefore not filtered; it is invariably clear and bright.



PLAN SHOWING THE LOCATION OF THE BERLIN-STRALAU WATER WORKS

(AFTER PIEFKE.)

HELIOTYPE PRINTING CO. BOSTON

Fig. 1.
Ansicht.

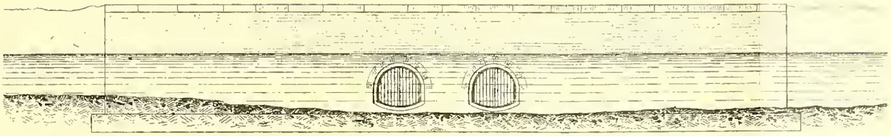


Fig. 2.
Schnitt C-D.

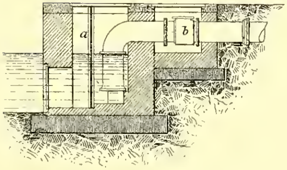


Fig. 3.
Schnitt A-B.

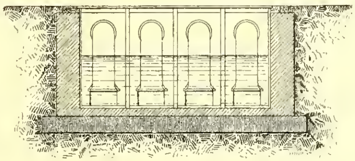


Fig. 4.
Schnitt E-F.

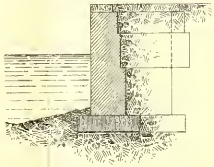
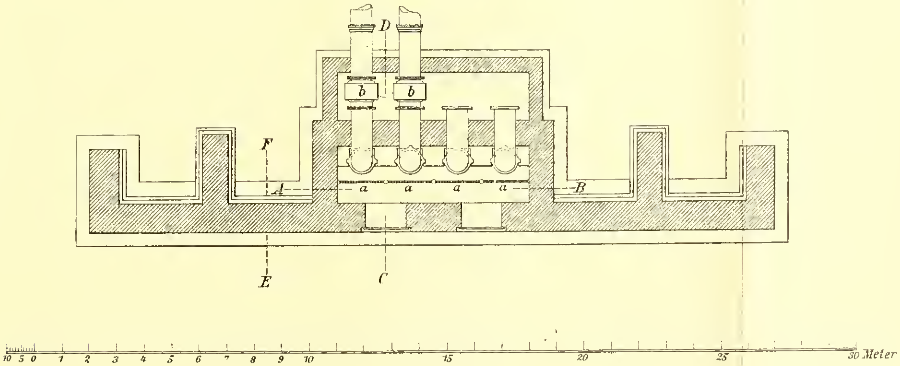


Fig. 5.
Grundriss.



INTAKE OF THE BERLIN-STRALAU WATER WORKS.
(AFTER PIEFKE.

HELIOTYPE PRINTING Cº BOSTON

Fig. 1.

Längsschnitt durch den Reinwasserkanal.

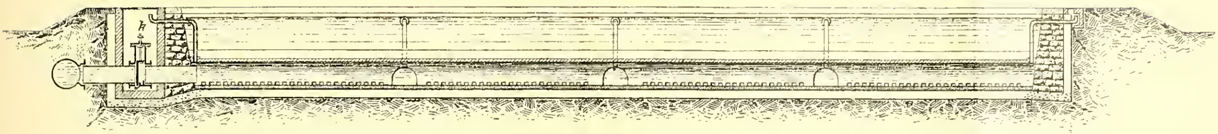


Fig. 2.

Querschnitt durch den Reinwasserkanal und das Überlaufrohr.

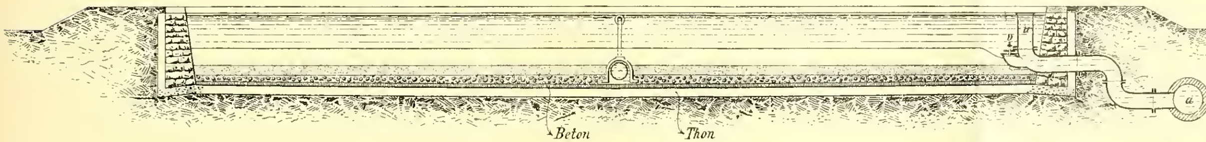


Fig. 3.

Schnitt durch das Zuflussrohr.

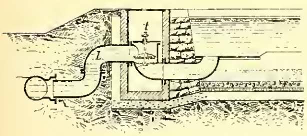


Fig. 4.

Ansicht des Sandhahns.

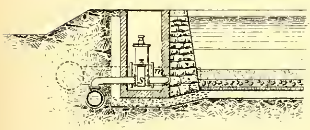


Fig. 5.

Aufsicht.

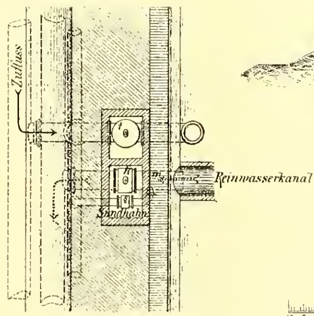
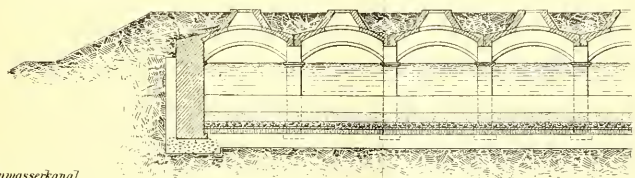
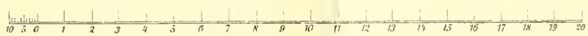


Fig. 6.

Schnitt durch ein überwölbtes Filter.





SECTIONS OF OPEN AND COVERED SAND-FILTERS. – BERLIN-STRALAU WATER WORKS.

(AFTER PIEFKE.)

HELIOTYPE PRINTING CO. BOSTON

Fig. 1.

Querschnitt.

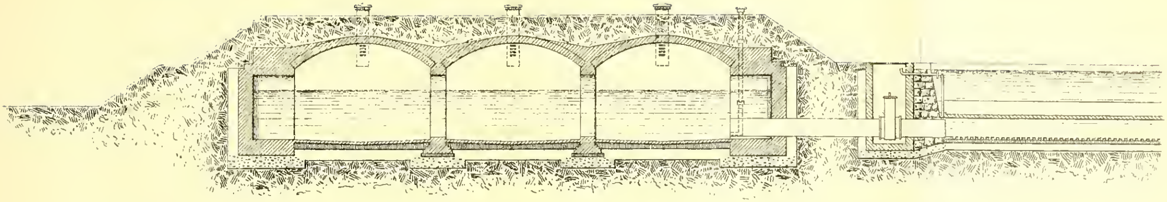
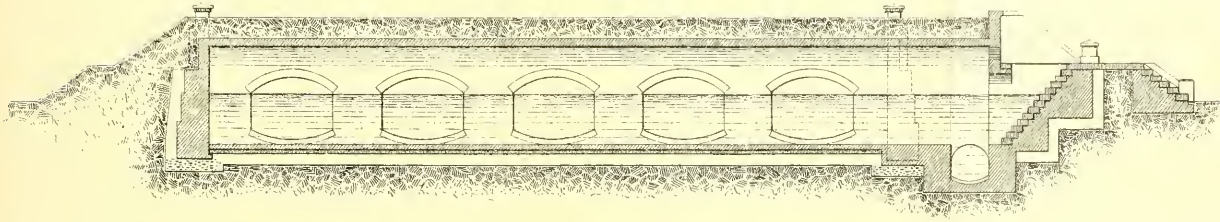


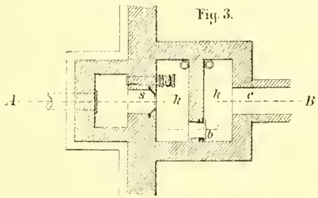
Fig. 2.

Längsschnitt.



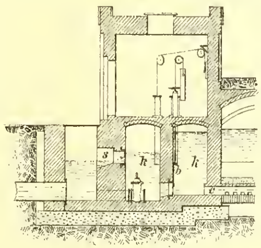
Vorkammer für die Filter der Station Tegel.

Fig. 3.



Grundriss.

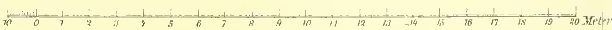
Fig. 4.



Schnitt A-B.

Fig. 5.

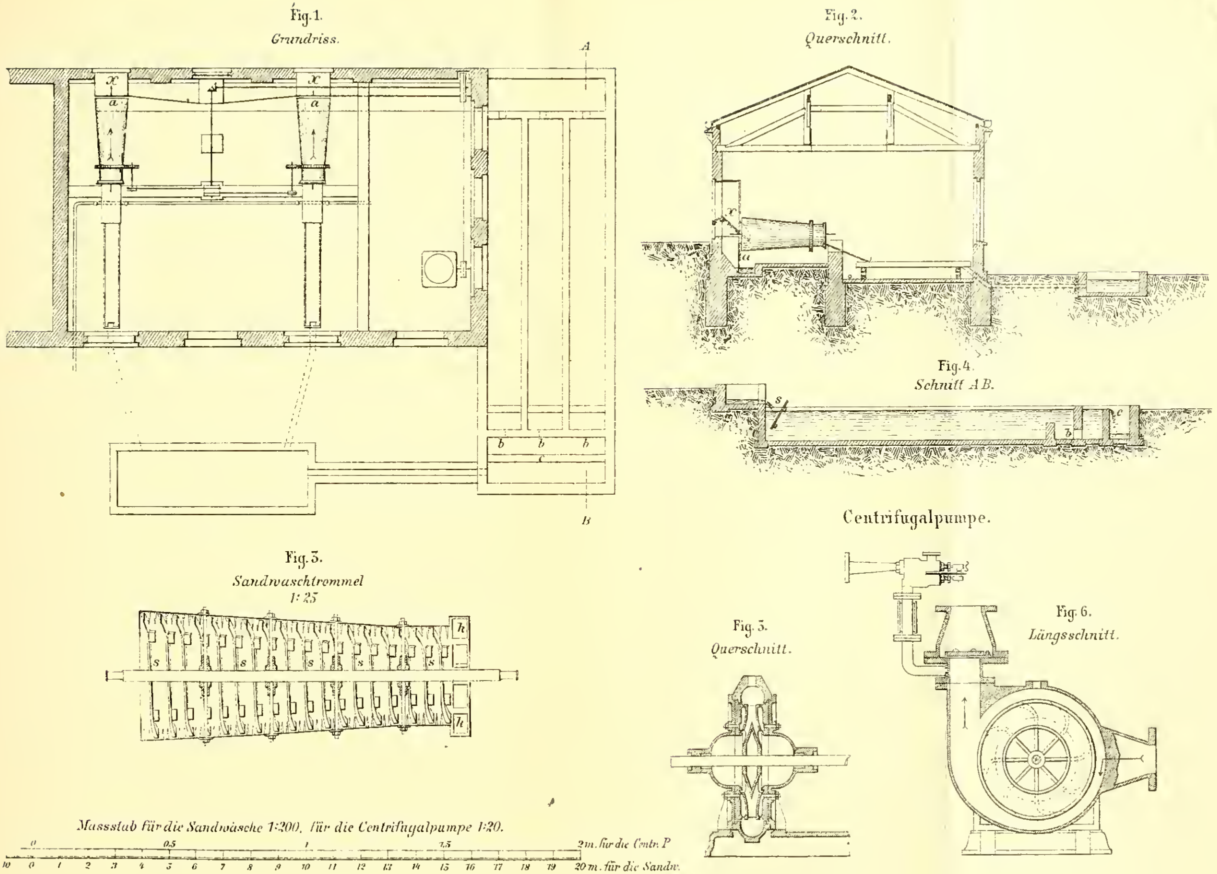
Ansicht.



THE RESERVOIR FOR FILTERED WATER AT BERLIN-STRALAU AND THE GATE-HOUSE AND GILL REGULATOR AT THE BERLIN-TEGEL WATER WORKS.

(AFTER PIEFKE.)

HELIOTYPE PRINTING Co, BOSTON



THE SAND-WASHING PLANT OF THE BERLIN-STRALAU WATER WORKS.

(AFTER PIEFKE.)

HELIOTYPE PRINTING Co, BOSTON

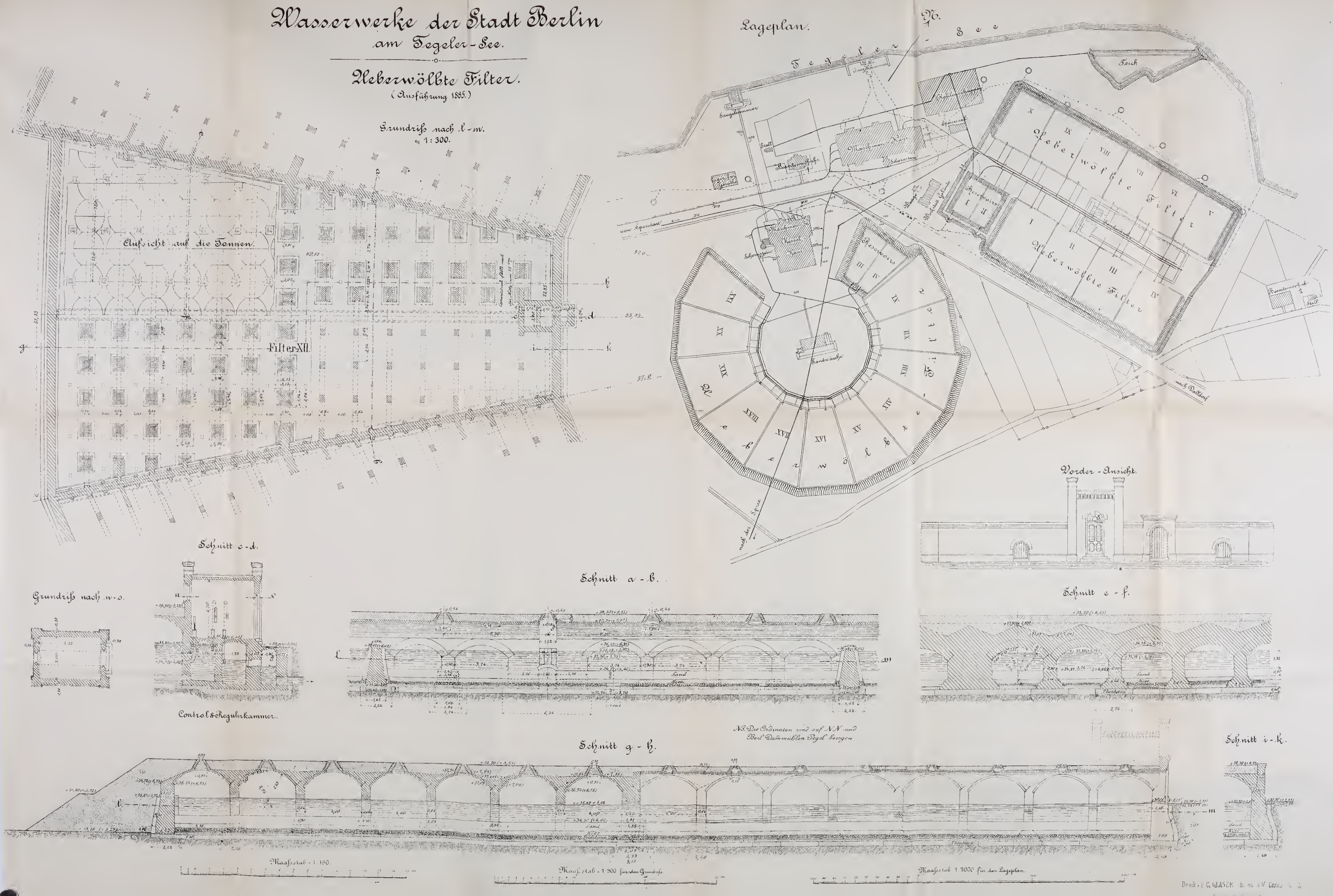

Wasserwerke der Stadt Berlin
am Tegeler-See.
Ueberwölbte Filter.
(Ausführung 1885.)
Grundriß nach l-m.
1:300.
Aufsicht auf die Tonnen.
Filter XII
Lageplan.
Tegeler-See
Teich
Ueberwölbte Filter
Reservoirs
Maschinen-Haus
Sandwäsche
von Spandau
nach Dalldorf
nach der Spree
Beamtenwohnh.
Stall
Vorder-Ansicht.
Schnitt c-d.
Grundriß nach n-o.
Control & Regulirkammer.
Schnitt a-b.
Schnitt e-f.
NB. Die Ordinaten sind auf N.N. und Beil. Dammühlen Pegel bezogen
Schnitt g-h.
Schnitt i-k.
Maaßstab 1:150.
Maaßstab 1:300 für den Grundriß
Maaßstab 1:2000 für den Lageplan.

PLATE IX. (after Reincke.)

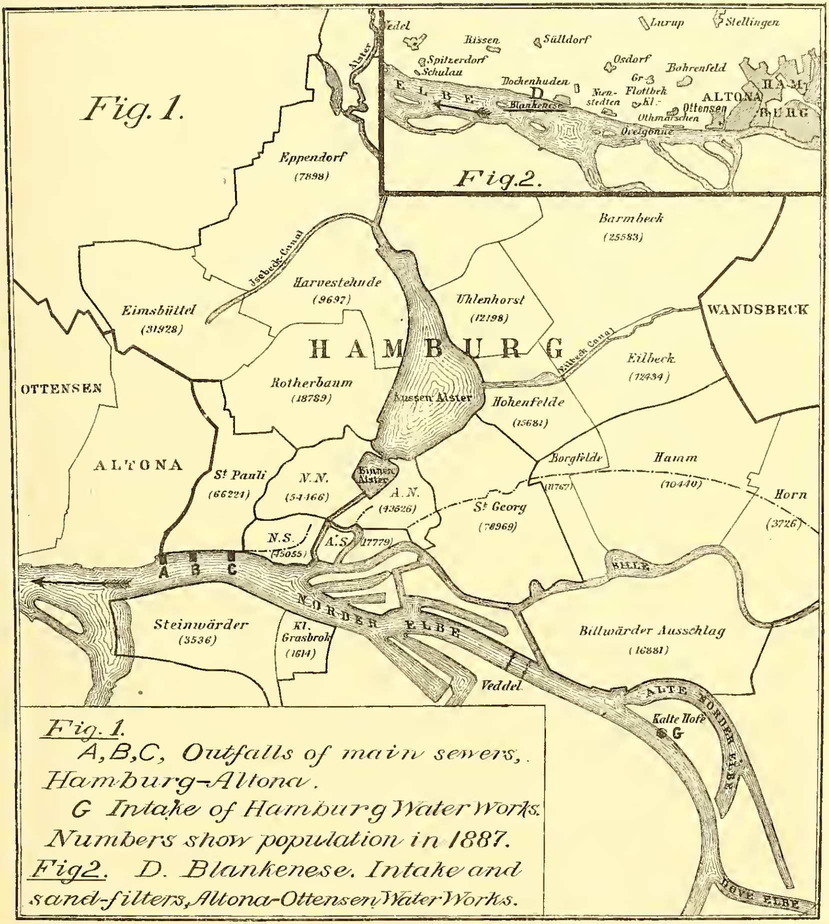


Fig. 1. A, B, C, Outfalls of main sewers, Hamburg-Altona.
G Intake of Hamburg Water Works.
Numbers show population in 1887.
Fig 2. D. Blankenese. Intake and sand-filters, Altona-Ottensen Water Works.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. VII. March, 1893. No. 3.

This Association, as a Body, is not responsible for the statements or opinions of any of its members.

QUARTERLY MEETING.

YOUNG'S HOTEL, BOSTON, MASS., DECEMBER 14TH, 1892.

The following members and guests were present :

ACTIVE MEMBERS.

Everett L. Abbott, Civil Engineer, New York city; Solon M. Allis, Malden, Mass.; Charles H. Baldwin, Boston, Mass.; Lewis M. Bancroft, Chairman Water Commissioners, Reading, Mass.; George E. Batchelder, Registrar, Worcester, Mass.; Joseph E. Beals, Supt., Middleboro, Mass.; William R. Billings, Taunton, Mass.; George H. Bishop, Civil Engineer, Middletown, Conn.; George Bowers, City Engineer, Lowell, Mass.; Dexter Brackett, Asst. Engineer, Boston, Mass.; George F. Chace, Taunton, Mass.; Charles E. Chandler, City Engineer, Norwich, Conn.; William F. Codd, Supt., Nantucket, Mass.; Freeman C. Coffin, Boston, Mass.; R. C. P. Coggeshall, Supt., New Bedford, Mass.; Byron I. Cook, Supt., Woonsocket, R. I.; Henry A. Cook, Supt., Salem, Mass.; F. H. Crandall, Supt., Burlington, Vt.; Lucas Cushing, Asst. Supt., Boston, Mass.; Horace L. Eaton, City Engineer, Somerville, Mass.; B. R. Felton, City Engineer, Marlboro, Mass.; F. F. Forbes, Supt., Brookline, Mass.; Z. R. Forbes, Asst. Supt., Brookline, Mass.; Frank L. Fuller, Civil Engineer, Boston, Mass.; L. L. Gerry, City Engineer, Dover, N. H.; W. J. Goldthwait, Marblehead, Mass.; J. A. Gould, Jr., Asst. Engineer, Boston, Mass.; Frank E. Hall, Supt., Quincy, Mass.; John Harris, Commissioner, Waltham, Mass.; John C. Haskell, Lynn, Mass.; Allen Hazen, Chemist, Lawrence, Mass.; Horace G. Holden, Supt., Nashua, N. H.; J. C.

Howe, Jr., Haverhill, Mass.; Patrick Kieron, Supt., Fall River, Mass.; George A. Kimball, Civil Engineer, Boston, Mass.; Wilbur F. Learned, Asst. Engineer, Watertown, Mass.; W. E. McClintock, Civil Engineer, Boston, Mass.; William McNally, Registrar, Marlboro, Mass.; Hiram Nevons, Supt., Cambridge, Mass.; Edward H. Phipps, Supt., New Haven, Conn.; Charles E. Pierce, Supt., East Providence, R. I.; Waldo E. Rawson, Supt., Uxbridge, Mass.; Walter H. Richards, Supt., New London, Conn.; George J. Ries, Supt., Weymouth Centre, Mass.; Henry W. Rogers, Supt., Haverhill, Mass.; George O. Sanders, President, Hudson, N. H.; William T. Sedgewick, Professor Biology, Inst. of Technology, Boston, Mass.; William B. Sherman, Mechanical Engineer, Providence, R. I.; Solon F. Smith, Supt., Grafton, Mass.; Frederick P. Stearns, Chief Engineer State Board of Health, Boston, Mass.; Eugene S. Sullivan, Supt. Mystic Division Charlestown, Boston, Mass.; Lucian A. Taylor, Civil Engineer, Boston, Mass.; Joseph G. Tenney, Supt., Leominister, Mass.; Robert J. Thomas, Supt., Lowell, Mass.; William H. Thomas, Asst. Supt., Hingham, Mass.; D. N. Tower, Supt., Cohassett, Mass.; W. H. Vaughn, Supt., Wellesley Hills, Mass.; Charles K. Walker, Supt., Manchester, N. H.; Horace B. Winship, Civil Engineer, Norwich, Conn.; Frederic I. Winslow, Boston, Mass.; George E. Winslow, Supt., Waltham, Mass.; E. T. Wiswall, Commissioner, West Newton, Mass.

ASSOCIATE MEMBERS.

James M. Betton, H. R. Worthington, New York city; A. H. Broderick, Chadwick Lead Works, Boston, Mass.; E. L. Ross, Chapman Valve Co., Indian Orchard, Mass.; C. H. Eherle, Crosby Steam Gage and Valve Co., Boston, Mass.; F. H. Hayes, Deane Steam Pump Co., Holyoke, Mass.; Charles H. Eglee, Contractor, Flushing, N. Y.; Henry F. Jencks, Pawtucket, R. I.; F. E. Stevens, Secretary Peet Valve Co., Boston, Mass.; H. L. Bond, Perrin, Seaman's & Co., Boston, Mass,; W. H. Van Winkle, Anthony P. Smith, Newark, N. J.; I. W. Dodge, Standard Thermometer Co., Peabody, Mass., Union Water Meter Co., Worcester, Mass.; B. F. Polsey, Walworth Mfg. Co., Boston, Mass.; Jesse Garrett, R. D. Wood & Co., Philadelphia, Pa.; H. A. Gorham, the George Woodman Co., Boston, Mass.

GUESTS.

Nath. H. Brown, Salem, Mass,; H. B. Burley, Nashua, N. H.; F. I. Chaffee, East Providence, R. I.; W. F. Clark, Boston Water Works; M. H. Crawford, Boston, Mass.; W. G. Curtis, Boston Water Works; Loring Farnham, Civil Engineer, Boston, Mass.; W. E. Foss, Boston Water Works; A. S. Hayes, St. Albans, Vt.; John H. Hurley, Salem, Mass.; W. F. Lawrence, Birmingham, Conn.; H. M. Lovering, Taunton, Mass.; W. T. Murphy, Boston Water Works; Dr. S. D. Presley, Taunton, Mass.; T. F. Smith, Grafton, Mass.; D. J. Sutherland, Lynn, Mass.; E. A. Taylor, Worcester, Mass.; S. H. Taylor,

New Bedford, Mass.; W. D. Taylor, Dover, N. H.; H. B. Tower, Cohassett, Mass.; H. A. Warren, St. Albans, Vt.; G. C. Whipple, Boston Water Works; W. F. Wyman, Brookline, Mass.

The Secretary presented the names of the following applicants for membership, and on motion of Mr. Fuller the Secretary was directed to cast the ballot of the Association for them, which he did and they were declared elected:

RESIDENT ACTIVE MEMBERS.

Harry B. Burr, City Engineer, Nashua, N. H.; Fred. I. Chaffee, Chairman Executive Board, East Providence, R. I. (29 Weybosset St., Providence;) William G. Curtis, Asst. Biologist, Boston Water Works, Brighton, Mass.; Wilbur D. Fiske, Water Commissioner, Melrose, Mass.; George S. Rice, Civil Engineer, 95 Milk St., Boston; Herbert E. Smith, Professor Chemistry, Yale Medical School, 430 George St., New Haven, Conn.; E. L. Wallace, Supt., Franklin Falls, N. H.; H. A. Warren, Supt., St. Albans, Vt.; Edwin A. Taylor, Constructing Engineer, U. S. Hotel, Boston; William D. Taylor, Supt., Dover, N. H.

NON RESIDENT ACTIVE MEMBERS.

George I. Bailey, Supt. Water Works, 61 State St., Albany, N. Y.; R. H. Bradley, Supt., Watertown, South Dakota; L. L. Doubleday, Secretary Water Co., Columbus, Kas.; William B. Gerrish, Supt., Oberlin, Ohio; J. O. A. Laforest, Acting Supt., Montreal, Quebec; W. G. Yorston, Constructing Engineer, Box 478, Truro, N. S.; J. B. Newhall, Supt., Staten Island.

ASSOCIATE MEMBERS.

M. H. Crawford, the Radford Pipe and Foundry Co. of Cincinnati, Cast Iron Pipe, address 523 Exchange Building, Boston.

The Secretary read the report of the committee appointed at the Holyoke convention on changes in the constitution as follows :

To the Members of the New England Water Works Association:

Gentlemen :—At the last annual convention, your President suggested that a change be made in the time and place of holding the annual convention, and for the reasons that many of the members are unable to leave their work in June, and that Boston is more accessible to the majority of the members, he suggested the advisability of changing the time of holding the annual meeting.

As this would require a change in the constitution of the Society, the subject was referred to your committee to consider and report at the December meeting any changes which they may deem advisable.

In order to obtain a full expression of the wishes of the members of the Association, your committee issued a short statement of the facts, asking for replies giving the individual preferences of the members. A copy of the circular referred to is appended to this report. About one-half of the members replied to our inquiries and from their replies the following statement is condensed :

	Resident.	Non-Res.	Total.
New England cities in June	53	12	65
Boston, in March	38	9	47
Boston, in June	7	5	12
New England cities in March	4	1	5
New England cities in September	2		2
Boston, in October		1	1
No preference	6	8	14
	110	36	146

Of the resident members 42 were superintendents or assistant superintendents of works, the class of our members whom it might be expected would be least able to leave their work during the month of June. Twenty two of these voted for June and 20 for March. The votes for New England cities and Boston were evenly divided, 21 votes each.

Thus it will be seen that the resident members taken as a whole do not desire a change from the present schedule. We would, however, call your attention to the vote of that important nucleus within the ranks of the resident members, viz.: The superintendents of water works. Their votes on this question were about evenly divided.

It is therefore apparent that a change from the present plan of holding the meetings is not desired by a majority of the members of the Association and your committee therefore recommend that no change be made.

Respectfully submitted,

DEXTER BRACKETT,
R. C. P. COGGESHALL,
W. H. RICHARDS.

(CIRCULAR.)

NEW ENGLAND WATER WORKS ASSOCIATION,
OFFICE OF THE SENIOR EDITOR,
BOSTON, MASS., JUNE 30TH, 1892.

Dear Sir :—At the annual convention of this Association, recently held at Holyoke, considerable discussion was had among the members as to the desirability of changing the time of holding the annual convention, in accordance with a suggestion advanced in President Holden's address.

The undersigned were appointed a committee to consider this question and report to the Association at the meeting in December such changes in the constitution and by-laws as may seem desirable.

Article VII, Section 1, of the constitution and by-laws reads as follows: "Four regular meetings of the Association shall be holden during each year, viz.: On the second Wednesday of March, June, September, and December; the June meeting shall be the principal meeting of the year, and shall be known as the 'annual meeting.' Special meetings of the Association may be holden at the discretion of the President."

It will thus be seen to be necessary to make a change in the constitution and by laws if the annual convention is to be held during any month other than June

Among those who favor the change, the suggestion is made that during the month of June, or, in fact, during any of the summer months, many of our members find it difficult or impossible to be away from their work for two or three days and that the convenience of the members would be enhanced and a larger attendance assured if the annual convention was held during the month of March. As this season would not be a pleasant one for sight seeing and as many of the New England cities cannot provide suitable accommodations for our meetings, it has been proposed in the future to hold all meetings in Boston, with the exception of the Fall Excursion.

This scheme would provide for the following named meetings, viz.: The annual convention in March, the Fall Excursion in September, meetings of one day each in November, December, January, and February.

Among those who do not desire a change from the present plan of meetings, the opinion is expressed that the holding of the annual conventions in June, in the different New England cities, occurring as they do at the pleasantest season of the year, afford most excellent opportunities for acquiring an acquaintance with our New England cities and towns, as well as giving a pleasant relaxation from the round of home duties. They feel that the series of winter meetings in Boston is as it should be, but that the Association and its work becomes better known by having the annual convention held according to the present plan.

Your committee desire a full expression of the opinions and preferences of the members upon this subject, especially from those who are in the habit of attending the annual convention.

Will you please express your views upon the enclosed postal? A prompt reply is earnestly requested.

Very respectfully,

DEXTER BRACKETT,
R. C. P. COGGESHALL, } Committee.
WALTER H. RICHARDS,

On motion of Mr. Harris the report of the committee was accepted.

Mr. Nevons suggested that an interesting subject for consideration at the next meeting would be the effect of electricity upon water pipes, and the Association extended an invitation to Mr. Charles Morse, of Cambridge, and

to Mr. Lee, of Boston, to be present at that time and speak upon that subject.

The President then introduced Desmond Fitzgerald, resident engineer, of the additional water supply and superintendent of the western division of the Boston Water Works, who gave an interesting description of the Boston Water Works, illustrated by lantern slides. Mr. Brackett followed, giving a description of certain features of the works, also illustrated by lantern slides. Mr. Walter H Richards followed with a description of the New London High Service, stereopticon views of which were exhibited.

[Adjourned.]

ADJOURNED MEETING.

Young's Hotel, Boston, Mass., January 11th, 1893.

The following members and guests were present:

ACTIVE MEMBERS.

Charles H. Baldwin, Boston, Mass.; Lewis M. Bancroft, Chairman Water Commissioners, Reading, Mass.; George E. Batchelder, Registrar, Worcester, Mass.; George Bowers, City Engineer, Lowell, Mass.; Dexter Brackett, Asst. Engineer, Boston, Mass.; Harry B. Burley, City Engineer, Nashua, N. H.; George F. Chace, Supt., Taunton, Mass.; R. C. P. Coggeshall, Supt., New Bedford, Mass.; Byron I. Cook, Supt., Woonsocket, R. I.; Henry A. Cook, Supt., Salem, Mass.; George K. Crandall, Asst. Engineer, New London, Conn.; William G. Curtis, Asst. Biologist, Boston W. W., Brighton, Mass.; Lucas Cushing, Asst. Supt., Boston, Mass.; Nathaniel Dennett, Supt., Somerville, Mass.; Albert B. Drake, Supt. Public Works, New Bedford, Mass.; Charles E. Drake, Civil Engineer, New Bedford, Mass.; Thomas M. Drown, Prof. Chemistry, Mass. Inst. Tech., Boston, Mass.; Horace L. Eaton, City Engineer, Somerville, Mass.; George A. Ellis, Civil Engineer, Boston, Mass.; F. F. Forbes, Supt., Brookline, Mass.; Z. R. Forbes, Asst. Supt., Brookline, Mass.; Frank L. Fuller, Civil Engineer, Boston, Mass.; Albert S. Glover, Boston, Mass.; W. J. Goldthwait, Morblehead, Mass.; E. H. Gowing, Boston, Mass.; E. A. W. Hammatt, Civil Engineer, Boston, Mass.; George W. Harrington, Supt., Wakefield, Mass.; John L. Harrington, Cambridge, Mass.; John C. Haskell, Supt., Lynn. Mass.; Allen Hazen, Chemist, Lawrence, Mass.; Horace G. Holden, Supt., Nashua, N. H.; Horatio N. Hyde, Supt., Newtonville, Mass.; Patrick Kieran, Supt., Fall River, Mass.; Thomas C. Lovell, Supt. Fitchburg, Mass.; Hiram Nevons, Supt., Cambridge, Mass.; Edward C. Nichols, Commissioner, Reading, Mass.; George H. Nye, Civil Engineer, New Bedford, Mass.; Edward H. Phipps, Supt., New Haven, Conn.; Waldo E. Rawson, Supt., Uxbridge, Mass.; George S. Rice, Civil Engineer, Boston, Mass.; Walter H. Richards, Supt., New London, Conn.; George J. Ries, Supt., Weymouth Centre, Mass.; G. A. Roulier, Supt.,

Flushing, N. Y.; A. H. Salisbury, Supt., Lawrence, Mass.; Chas. W. S. Seymour, Supt., Hingham, Mass.; William B. Sherman, Mechanical Engineer, Providence, R. I.; John D. Shippee, Supt. and Secretary, Holliston, Mass.; George A. Stacy, Supt., Marlborough, Mass.; Edwin A. Taylor, Civil Engineer, Boston, Mass.; Lucian A. Taylor, Civil Engineer, Boston, Mass.; M. M. Tidd, Boston, Mass.; S. Everett Tinkham, Asst. Engineer, Boston, Mass.; W. H. Vaughn, Supt., Wellesley Hills, Mass.; Charles K. Walker, Supt., Manchester, N. H.; Joseph Watters, Commissioner, Fall River, Mass.; Robert J. Thomas, Supt., Lowell, Mass.; E. L. Wallace, Supt., Franklin Falls, N. H.; Horace B. Winship, Civil Engineer. Norwich, Conn.; Frederick S. Winslow, Boston, Mass.; George E. Winslow, Supt., Waltham, Mass.

ASSOCIATE MEMBERS.

James M. Betton, H. R. Worthington, Boston, Mass.; A. H. Broderick, Chadwick Lead Works, Boston, Mass.; M. H. Crawford, Radford Pipe and Foundry Co., Boston, Mass.; Charles H. Eglee, Contractor, Flushing, N. Y.; G. A. Taylor, and H. N. Libbey, Gilchrist & Taylor, Boston, Mass.; J. A. Tilden, Hersey Mfg. Co., South Boston. Mass.; Mr. Snow, Thomson Meter Co., Brooklyn, N. Y.; J. P. K. Otis, and G. H. Carr, Union Water Meter Co., Worcester, Mass.; George B. Wood, R. D. Wood & Co., Philadelphia, Penn.; H. A. Gorham, the George Woodman Co., Boston, Mass.

GUESTS.

R. B. Allen, H. P. Beals, A. A. Blossom, Salem, Mass.; Frank P. Brown, F. W. Clark, Brighton, Mass.; Mr. Cook, Cambridge, Mass.; John Cornell, Waltham, Mass.; Mr. Davis, Brookline, Mass.; A. H. French, Brookline, Mass.; W. E. Foss, Boston, Mass.; John Gardner, Fall River, Mass.; Mr. Hill, Waltham, Mass.; John F. Hurley, Salem, Mass.; H. L. Lincoln, Cambridge, Mass.; L. D. May, J. J. Moore, Boston, Mass.; Mr. Morse, Cambridge, Mass.; Dr. Shea. Lawrence, Mass.; L. H. Taylor, New Bedford, Mass,; Wallace Whiton, Weymouth Centre, Mass.; E. Worthinnton, Jr., Boston, Mass.; W. T. Wyman, Boston, Mass.

The Secretary presented the following applications for resident active membership :

Frederick W. Clark, Clerk on Boston Water Works at Chestnut Hill Reservoir; E. Worthington, Jr., Hydraulic Engineer, 637 Exchange Building, Boston; Ernest H. Brownell, Instructor Brown University, Providence, R. I.

On motion of Mr. Brackett the Secretary was directed to cast the ballot of the Association for the candidates, and they were declared elected.

Mr, Cook of the Cambridge Press was called upon by the President and responded with a humorous speech.

Mr. George A. Ellis, formerly President of the Association, was called upon by the President and he spoke as follows :

It gives me great pleasure to meet you again Mr. President and gentlemen of the Association, after so many years, even if I have to meet you almost as a stranger, as I did Mr. Coggeshall, who not only asked me my name but had to ask me my initials before he knew who I was. (Laughter.) I would say that while I have been absent from you I have found everywhere I have been evidence of the influence of this Association among water works men. And I think the reason is, that whenever any subject of interest is suggested, there is found among our members some who have made a study of the subject and are willing at meetings like this to give their experience. I have read with great interest the reports of your experience meetings, and they have impressed me as very valuable. I think I can give no better advice than to say that you cannot do better than to make a study of that which comes nearest to your hand. (Applause.)

Mr. C. H. Morse, of Cambridge, gave an interesting talk on "Electrolysis of Water Pipes." Mr. Allen Hazen, Chemist at the experimental station at Lawrence, gave an account of his work in selecting sand and gravels for the filter constructing there; and Mr. Edwin P. Gardiner, Superintendent, Norwich, Conn., read a paper describing an efficient artificial light for outside night work.

An invitation was received from Mr. Pearson of the West End Railroad company for the members of the Association to visit the West End Power station on the forenoon of the day of the next meeting. Accepted.

The subject of the size of pipe permissible for fire protection for manufactories and the charge for the same was discussed by Mr. Walker, Mr. Nevons, Mr. Stacy, Mr. Freeman and Mr. Fuller.

[Adjourned.]

ELECTROLYSIS OF WATER PIPES.

BY

Mr. C. H. Morse, of Cambridge, Mass.

Mr. President and Gentlemen of the New England Water Works Association:— When my friend Mr. Nevons about two years and a half ago came to me in the corridors of the City Hall and said: "Mr. Morse, what effect is the connecting of these wires to our water pipes going to have?" I remember of saying to him at that time: "The effect will be something very slight, I anticipate no trouble from it; you will probably be in your grave before any water pipes are injured by electricity." And then, again, about two months and a half ago, when Mr. Nevons again came to me and said: "Mr. Morse, do you suppose that this electric business is having any effect on our pipes?" and I answered him in an entirely different way, saying, "Most certainly, I haven't the slightest doubt but what it is having an effect," he gave me a look as much as to say, "Why, Mr. Morse! You never think twice alike, do you?" (Laughter.) And it did seem so, really. And I remember he rather brought me to an account for that, and when he said, "You have changed your mind, haven't you?" I gave him some such reply as this: That in electrical matters two years and a half certainly do make ancient history. And I think that is particularly so in regard to the development of the transmission of power by electrical energy. We have had many changes in this department of science within that time. I think I can illustrate it no better than to say that the generators which were developing power for the West End Railway company two years and a half ago are now obsolete; that the motors which were under the cars two years and a half ago would not be tolerated now by the company; new motors have been placed in service, larger ones, water-proof motors, gearless motors which make less noise, motors which are made dust proof by iron cases; and there are the single reduction motors, the gears of which run in oil, making the operation exceedingly quiet. So I feel justified in saying that the last two years and a half in some departments of electrical work have made ancient history.

Electrolytic action is not a new thing. In the year 1300 note was made of this action. Although the Faradic battery was not discovered till 1799 yet electrolytic action has been known for 500 years at least. Iron tools of miners working in copper mines, were found covered with a thin coating of copper caused by electrolytic action. So you see it is really nothing new which we are discussing today; it is merely a new, accidental application of the subject.

In order that you may understand the whys and the wherefores of this, you will excuse me if I make comparisons and go back a little into the theory of hydraulics and electricity, comparing the flowing of the electric current with

the water works system. And this is why it gives me pleasure to speak to men of your business, you will so quickly grasp the situation. I think sometimes when these comparisons are made the speaker does not go quite far enough back. All power emanates, of course, from the sun's heat. We should start from our water works, when we speak about the pressure and fall of potential at the source of supply, the sea. The heat of the sun evaporates the water, taking up only the pure water and leaving the salt, the air becomes saturated with this moisture and it flows back steadily into the interior where it meets colder streams of air, if you please to call them streams, or currents, and condensation takes place. Thus we have our highest potential in a water works system in the cloud. The condensation goes on till the drops of water are formed. The highest part of the water works system is in the cloud. The drops fall to the earth and part of our energy is lost, but the power is not noticed, as it is distributed over such a vast area that the heat effects developed are hardly apparent. The water falls into the water basin and runs back into the store house, as we might call it, the reservoir, and here we generally begin when we compare hydraulics and electricity. Then we have our large mains leading to all parts of our cities and towns, gradually growing smaller and smaller until you get to the faucets in the houses.

Now, if we should derive only power from our water pressure, and use it merely through water motors, the ideal place to put the motor, of course, would be the sea level; then we should get our maximum potential, if we had our mains big enough, we should get our full potential at the water wheel, we should get the full head, so to speak.

An ideal electric power system should be built on exactly the same principles. We have in the city of Boston in the West End Railroad system, three separate power houses, one at East Cambridge, one on Albany street and one in Allston, not very far from Cambridge. These power houses are the reservoirs. We could, if we chose, go back of this reservoir to the sun's heat again and think of the coal being formed, the trees growing centuries ago in the tropical regions, storing up this immense amount of potential energy, this coal then placed under the boilers and producing steam, that steam transformed into mechanical energy in the steam engine and the steam engine giving up its power to the dynamo, which sends out in the form of electricity 95 per cent. of the power given to it. Now, in our electrical plant we really get our highest potential at what we call the positive pole of the dynamo. The current of electricity flows out from the positive pole of the generators. These generators are coupled together, say in multiple, that is, all the positive poles together. As two or three steam fire engines may all throw their water into one line of hose, so all the generators throw their energy from the positive side of the dynamo on to the feed wires. These feed wires radiate to all parts of the system. From the East Cambridge power house, for instance, they extend to Arlington, all parts of Cambridge, some parts of Boston, to Everett, Charlestown and Somerville. Now, then, we have these immense main feeders radiating out from the station, upon which the current flows. They should be of sufficient capacity to carry the current without a fall of pressure, the same as with our water

mains, when we draw all that the generators are capable of developing with safety at the end of our lines.

Now, if I may refer to a water works system again, every particle of current which leaves these feeders and goes through the cars must return to the negative pole of the dynamo, as in the water works system every particle of water which runs out from the faucets must find its way back to the sea level. In the same way the electric current comes back. We lose in our water works system a large amount of our power in consequence of distributing the water at a higher level than the sea level, in the electric system this should not be necessary. The current goes through the feeders to the trolley wires, through the trolley down the pole to the car, through a concealed wire to the motor under the car. This motor should consume all the energy, and when the current leaves and goes into the rail it should have an easy path upon which it can return, so easy that there will be no loss of pressure noticeable on the return. When electric cars were first put in operation in Cambridge they depended upon mother earth, the water pipes, the gas pipes, and anything over which the current could flow, to convey it to the station or act as a sewer. No thought was given to the loss which would result to the company from doing this, to say nothing about the effect upon our pipes. I can perhaps illustrate this loss by saying that three months ago in parts of Cambridge the loss of pressure due to the power which was required to force this current back over this uncertain path was 20 per cent. Now, when I tell you that the central stations of the West End Railroad company have a maximum capacity of 12,000 horse power, which would give sufficient current for 24,000 arc lamps the same as are used in our streets, or 120,000 incandescent lamps, such as we have in this building, you get an idea of the power which is being sent out. When you think of that current returning, as it has been obliged to return, you can see that there must be an immense amount transmitted over our pipes.

The effect of this was called to my attention by the superintendent of the Cambridge Water Works, who is ever vigilant in these directions, and a series of tests were made to ascertain the quantity, and a little reasoning was done to determine the consequences. Electric currents have nearly the same laws as hydraulics. You take a 2-inch pipe and a 4-inch pipe, not counting in friction, the 4-inch pipe will carry four times as much water as the 2-inch, the amount varying directly as the square of the diameters. The current of electricity which will flow through two wires side by side is in the same proportion, the larger the wire the larger the current, varying as the squares of the diameters of the wires. We use a little different form from what you do, aud instead of speaking of diameters we speak of wires now as of so many circular mills. This gives us immediately the idea of the amount of current which will pass over those wires. It is simply the diameter in thousandths of an inch squared.

Now, when we come to the word resistance, I want you to bear in mind this : The resistance is the same as it is in a water pipe, in one sense; you get small resistance through a large pipe, and the smaller the resistance the more water will flow. And the same rule holds with wire; the smaller the resistance

the more electricity will flow through it. If several paths are open we say the current divides inversely as the resistance. If the frictional effect or resistance of a wire is small, large amounts will flow. If we have two water pipes side by side running from the same reservoir, and we are drafting at the same point, if the pipes are of the same frictional effect, we shall have the same current of water flowing through the two pipes. Now, if we have two wires side by side attached to the same machine, the current will divide and will flow through those wires inversely according to the resistance. The larger the wire, the less the resistance and the more the flowage, provided they are of the same metal.

When the railroad company put in their power plant, they ran large numbers of feeders, as we call them, and one wire between the rails and attached the two rails to this return wire, so that the current, as I said before, will go to the car through the motor to the wheels, to the rails, and get along as best it can back to the station. This became very soon an uncertain path, as it was found that electrolytic action took place upon this wire and it disappeared in places. They thought at first that it was due to something in the soil, but it was very soon traced to the same enemy which you have to contend with, that is, electrolytic action. I remember the practical experience we had with these dead rails, as we call them. When this wire was eaten off and a car came on to that section, if by any chance you placed one foot upon the rail and another upon the ground near it, shocks could be obtained. That happened simply in this way. The current must get back to the station, and it would take to the rail, which was not well grounded, would go up one leg of the man who stood on the rail and down the other to the earth, especially if the earth was a little moist, dividing again inversely according to the resistance.

The effect was so great that the West End Railroad company made a complete change and reversed the conditions. It would be as if you started with your water works system by pumping the water from the sea into the sewers, forcing it up out of the sewer pipes and back through the faucets and through the mains to the reservoir. That is, they attached the other pole to the earth to remedy this difficulty, and instead of sending the current out over the feeders they commenced about a year and a half ago to force it out through the ground, have it go up through the cars and back through the feeders. When I heard of this I immediately concluded we should have trouble from it, and that is why I told my friend Nevons so decidedly I had no doubt it would have an effect; and now I will state some of the effects that have been noticed in Cambridge.

Mr. Nevons and I went to the different places where we had traced these difficulties, or where they had been called to our attention rather, and found that lead pipes had disappeared in a short space of time, some even in six or eight weeks. Iron pipes had been tried with the same result, also galvanized iron ; brass pipe had been put in and deterioration was noticed at once. Rustless iron was tried, and it did rust decidedly. (Laughter.) Well, it was not the work of any mysterious agent, but was the result of what almost all of you have seen in school experiments, that is, the decomposition of water. The

current left the West End power house at East Cambridge, it flowed through the ground, and of course, divided according to the resistance, and took to whatever conductor came in its way. It took to the rails, the water pipes and gas pipes. Now, we get no action except at what we call the positive pole. That is where the current is flowing out of the pipes, where it takes to the pipe there is no action. The current flowed along on the pipes, and in this particular case, it got down on to Bridge street, which is near Charles river, and flowed along our supply pipes on the wharves and here it had to get across the river to propel the cars in Boston. Where it left those pipes action took place.

Well, the remedy, the quick remedy for that, of course, was very apparent, that is, to reverse the current. So the officials of the West End Railroad company were invited to a conference with the Water Board and myself, and I am pleased to say the company were willing and anxious to do anything in their power to obviate this difficulty. A certain amount of credit belongs to them for that, although, of course, they had a reason for wanting to do it themselves. They were losing anywhere from 5 to 20 per cent. of their power in this return; and when you reckon the loss on 12,000 horse power it is quite an item, if they could save 5 per cent. of that by the investment of a large amount of money it was very desirable for them to do it. They were consequently perfectly willing to take hold of this matter. It was suggested at that time that a reversal of the current might be a good thing. Now, I can illustrate to you in a moment why that would have an effect. The current was reversed, and now takes to our water pipes in just the same places that it left them before. As I told you before, there is no action at the point of contact, where it goes into the pipe; it is only where it leaves it. Therefore you would expect a very rapid deterioration where it left the pipes near the power house to go in to the machines there; of course we had to fix the pipes so the current would not leave them through the earth. The leaving through the earth would cause this effect. A difference in potential of 2 volts—our system of pressure; you call it pounds—in a current flowing from one piece of metal to another through moisture causes the decomposition of water, and water forms into the two gases, oxygen and hydrogen, at this place. Now, we speak of the oxidation of an iron pipe due to the attacking of the pipe by this gas. If it were pure oxygen there you can see we should have a very rapid attacking of that pipe. Then, we must find some means by which we can get the current off the pipe without having it go from the pipe to the earth, and we do it by soldering very heavy copper wires to the pipes in various places and carrying these copper wires into the power house and attaching them to the negative poles of the machines, so the current has an easy path over which to leave the pipe. Of course the result is we get no electrolytic action because we don't have the current leaving the pipe through the earth connection, but through a solid metal connection.

Observations were made by several of the water works employees unintentionally. Some of the other gentlemen present could tell you about those, perhaps, better than I. Such an immense amount of current was flowing over the pipes that upon attempting to make a joint by putting oakum around

the pipe, it was found that the electric arc was often sufficient to set fire to the oakum, frightening the men considerably, I imagine. This of course would not necessarily indicate a very high potential, but proved the presence of a large quantity of current in the earth. Tests were made in different parts of the city by means of instruments adapted for the purpose, and we found between North Cambridge, Harvard Square, Central Square and East Cambridge a fall of potential all the way from 25 to 45 volts. Now, you can reckon the percentage as well as I. There should be no fall of potential, but there was a loss, as I said, of from 25 to 45 volts, from 500 volts which is the maximum pressure, making more loss than can be allowed with economy. When we attached to the negative pole of the machine and made our tests from Harvard Square, we found a loss of 100 volts, or 20 per cent., of the pressure. You can now see, as I said before, why the company was very ready to take hold of this matter.

How are we to remedy the difficulty? I know of no way by which we can use the single trolley wire system and overcome this difficulty without putting up an immense amount of overhead returns, through which the resistance will be reduced to almost nothing. How far the company will be willing to go in this I cannot say. Their spirit has been so admirable in the past I have no right to suppose but what they are willing to carry it to that extent. Certainly the city will require it carried to such an extent that the pipes will be in perfect safety. The maximum amount of current which can be allowed to go over them I am unable to tell you at present, but a series of experiments are being conducted now at my house to determine this. I have some pipes buried in the earth, the current flowing over them, and I am watching carefully the deterioration daily. I am in hopes to make a report soon to the Water Board upon the maximum amount which can be allowed to flow upon iron pipes from which we will have no effect.

By doing what we did do, reversing the current and attaching our water pipes to the negative pole of the dynamo, we hurt one of our old friends seriously, that is, the Gas Company. You see the effect. The current will flow on the water pipes, and it has an easy chance to leave them through their connection with the negative pole of the dynamo. Now it flows along on a gas pipe and as soon as it can it will leave the gas pipe to take to the water pipe. I felt it my duty to make this clear to the president of the Gas Company, and called his attention to it, saying that something ought to be done to protect him, and a conference was had between the railroad people and the Gas Company, and I was invited to be present. At that time we made an arrangement with the company which will help it somewhat in that direction, and will help us as well as them. We propose now to connect the gas pipes and the water pipes together in all parts of the city. It will be done in buildings. A man from the West End company has been appointed who goes as a gas man to the different stores and factories, and in those places he will solder a wire to the gas pipe and also to the water pipe. This can do no injury to either, but will decidedly help both companies.

You will be a little interested, perhaps, to know of one or two experiments which we have tried in East Cambridge when investigating this subject. Mr. Nevons will be perfectly familiar with the new engine house at East Cambridge. It is not yet occupied. There is an old supply which comes in from one street that connected with the old house, and a new supply comes in from Otis street, I believe. The mains are connected together at the corner of Third and Otis street, and this engine house is on the corner. Now there is sufficient difference in potential between those two pipes so that if they are connected together by a medium sized copper wire, about a No. 18, it will heat the wire so hot you can't bear your hand upon it. There is sufficient power to run a good sized motor, and I suggested to the engineer that he put a motor in there and run a planing mill and a few other little industries to help out that section of the city. It is a matter of fact that if we could save all this energy which is being thrown away, we could run a large factory. In fact, if we run a copper wire from East Cambridge to Harvard Square I think at times there would be no difficulty in running the whole University Press by this wasted power.

It was a little surprise to me the way they attempted at first to return the current. Iron carries a current of electricity not as readily as copper; it has seven times the resistance. Now, there are girder rails, that have, we will say, 10 square inches, some of them have as high as 14 square inches sectional area. That would have a carrying capacity equal to a piece of copper 2 inches square. And yet these rails are bonded by a No. 4 copper wire, a wire smaller than a lead pencil. It seems quite ridiculous that they should ask this little bit of fine copper wire to carry as much current as a big rail, where they could have a piece of copper wire, as I said before, for these big rails, of at least two square inches sectional area.

There is another remedy also which we hope to carry out early in the spring, and that is to abolish completely this return wire between the rails, by cutting it into sections of about 400 feet, and connect each of these sections with the return wires. Most of the current will then return by these copper wires. Of course, some of it, as I said before, will flow over the water pipes; that cannot be helped as long as one side of the machine is connected with the earth.

Another remedy which is to be adopted, is a special line of feeders attached only to the water pipes; that is, a feeder will be run from the central power house to the different parts of the city, which will not be connected with the machines at all, but will be connected with the water pipes at the central power house and with the pipes in all sections of the city. This will also materially reduce the electrolytic action.

I have occupied more time already than I ought, but if any member of the Association desires to ask any questions I should be pleased to answer them.

The President. Gentlemen, this subject is open for discussion. I understand that there are two classes of persons, those who do not claim to know anything about this subject, and those who know a great deal more

than they care to tell. That being the case, I do not dare to call upon any body, but I should be glad to hear from any one, and Mr. Morse is ready to answer any questions.

Mr. Hazen. I would like to ask if the destruction of the pipes is entirely from the outside, or whether it is from the inside as well?

Mr. Morse. It is entirely from the outside, where the current leaves the pipe. We should have almost the same effect if there was no water in it. Where the current leaves the pipe it makes little pit holes in it as big as the end of your finger or thumb, a little crevice which will work clear through the pipes.

Mr. Hazen. Is the ferric oxide left there?

Mr. Morse. You would be surprised to see how much is carried away, and just what becomes of it I haven't been able to determine yet.

Mr. Holden. Does it affect one kind of pipe more than another?

Mr. Morse. Any kind of metal pipe would be affected. A remedy has been tried that I think will be successful in some sections, that is, the placing of the pipe in cracked stone. I think this has a decided effect. And, also, the placing of the pipe in cement, where the supplies go through muddy places, would be desirable.

Mr. Holden. Wouldn't a cement covering answer?

Mr. Morse. Yes, sir. But let me explain that we should get the flow of the current through a cement lined pipe, and if the supplies were not covered we should get the action on the supplies.

Mr. Tidd. I should like to ask if those spots you speak of are rust spots or holes apparently drilled into the pipe?

Mr. Morse. I think it is probably due in iron pipes to a very rapid oxidation of the pipe. It is quite difficult to make a deposit of iron, although it has been done repeatedly and is being done in some instances commercially. The effect is, however, I think, undoubtedly rapid rusting due to the formation of oxygen and hydrogen at the positive pole.

Mr. Tidd. I asked the question because in my experience in dry docks I have noticed that almost every steamer that comes into a dry dock has on the back side of the propeller, I mean the side towards the ship, pit-holes drilled into the propeller, sometimes half an inch in diameter and oftentimes as big as your hand, and drilled sometimes completely through the blade, but always starting from the back side. I asked the question because I have wondered whether there was any electrical action between the propeller and the water in friction. I have noticed that in every iron propeller I ever saw taken from a steamer, which had been in use one or two years; they always have these holes on the back side of the blade, and I didn't know but it might be something of that sort.

Mr. Morse. I am not able at present to account for that.

Mr. Coggeshall. I think perhaps some of us would be interested to know how much damage this has caused in Cambridge. I don't think it is generally known how serious a matter it is.

Mr. Morse. We would give a good deal if we knew. We simply know there has been damage, and of course a large amount of injury has not been located yet. We have discovered some of it, but we do not know how soon dozens of pipes may give out which have not yet been quite destroyed.

Mr. Gardner. Do I understand that the return wire between the rails has suffered this deterioration so it has been eaten *all* away?

Mr. Morse. Yes, I have seen that in several instances. Three years ago complaints came to me that in a certain section of the city if a horse stepped on a rail he would be knocked down. I investigated, and found that the wire was reduced to almost nothing, leaving what we call a dead rail. You can see the effect at once. If a car came in on that section, the current had to get back through the ground, and it would go up through a horse's forward legs, pass through his body and down through his hind feet, and the result was a severe shock.

Mr. Gardner. Was this a small wire?

Mr. Morse. About as large as a lead pencil.

Mr. Gardner. Did this deterioration in the wire occur in spots or was it general?

Mr. Morse. I don't know how general. I know that in some sections of the city they have been forced to make this return a covered wire, almost insulating it, so they wouldn't get this effect. It varied in different soils.

Mr. Gardner. The reason I asked the question was because I wondered whether it was not possible that there was something in the soil that facilitated that action.

Mr. Morse. I think there is no doubt about it; there is a very great difference in different soils.

Mr. Gardner. If that wire had been larger do you think the action would have been the same, or was it due to the incapacity of the wire to conduct the current? In other words, had the wire been large enough to conduct the current readily would there have been this disintegration?

Mr. Morse. No, I think there would not. If the current could flow back over the rail and wire very easily, much easier than it could leave it and take to the water pipes, the amount of the electrical action would be so small it would have been years before we discovered it. Several months ago we were unable to locate grounds on our fire alarm system, and I wrote to the West End company complaining of the size of their return wires, and last April they commenced running a return wire just to overcome that difficulty.

Mr. Gardner. Wouldn't the remedy be to have a very large return?

Mr. Morse. Yes, that is it exactly, to have the return so large that there can be almost no resistance to it. The question which we are considering now is how much current we can allow with safety on our water pipes. It is not possible under the present system to make it so that there will be absolutely *no* flow, and the question is how much we can allow with safety.

Prof. Drown. I would like to ask Mr. Morse if it were possible to cover the pipes completely with a non-conducting coating heavily coated with asphalt, whether there would be any deterioration?

Mr. Morse. If the pipes could be insulated from the soil in which they are placed there would be no action.

THE HIGH SERVICE WATER WORKS SYSTEM OF NEW LONDON, CONN.

BY

Walter H. Richards, Engineer.

The city of New London is supplied with water by gravity from a large storage reservoir situated six miles from the city. Until 1889 the supply main consisted of 24-in. pipe for a distance of about 6000 feet from the reservoir, where it was reduced to 16-in., continuing of that size to the city. At that time, with an estimated average daily draft of 1,250,000 gallons, the pressure in the higher portions of the city, 100 to 120 feet above mean high tide, was so seriously reduced as to deprive some houses of water during a portion of the day, and the 16-in. main was paralleled with a 20-in. But as the higher portion above referred to would still have a pressure of only 30 lbs., or less, it was decided to cut it off from the lower portion of the city, and increase this pressure to about 50 lbs.

The high service district was occupied almost exclusively by residences, and as the quantity consumed was consequently small the cost of maintenance of a steam pumping plant would have been out of proportion to the results obtained. For this reason a tank was built at an elevation sufficient to furnish the desired pressure, and the tank supplied by pumping from the supply main, the pump being driven by a hydraulic engine, actuated by the water consumed in the lower part of the city. If, for any reason, the tank is shut off from the high service, a check valve between the high and low services furnishes a temporary supply under low pressure.

As by the system adopted the pumping is continuous and approximately in proportion to the draft, the tank was small, holding but 90,000 gallons, being designed to furnish water for such small fires as are likely to occur in a residence district, and to supply any temporary disproportion between the draft in the two districts.

A tank elevated on a tower was adopted in preference to the ordinary stand-pipe, because water in the lower portion of a stand-pipe, being below the level of the reservoir, would be useless, and would lie stagnant.

The tower rests upon four heavy granite masonry piers laid up in cement mortar. These piers are 10 feet square at the base, and 6 feet square at the top, surmounted by pillar blocks of cut stone, 4 feet square and 10 inches thick. The piers are 10 feet deep, and rest on a clayey hardpan formation. Two $1\frac{1}{2}$-in. bolts run from the bottom to the top stone, and the iron bed plates are secured to the pillar blocks by four 1-in. bolts running through this stone, the whole structure being thus fastened together.

The tower consists of four wrought iron lattice posts resting on wrought iron bed plates which support nine plate girders, 4 feet in depth. The posts are 36 feet c. to c. at the bottom, and 20 feet c. to c. at the top, and are fas-

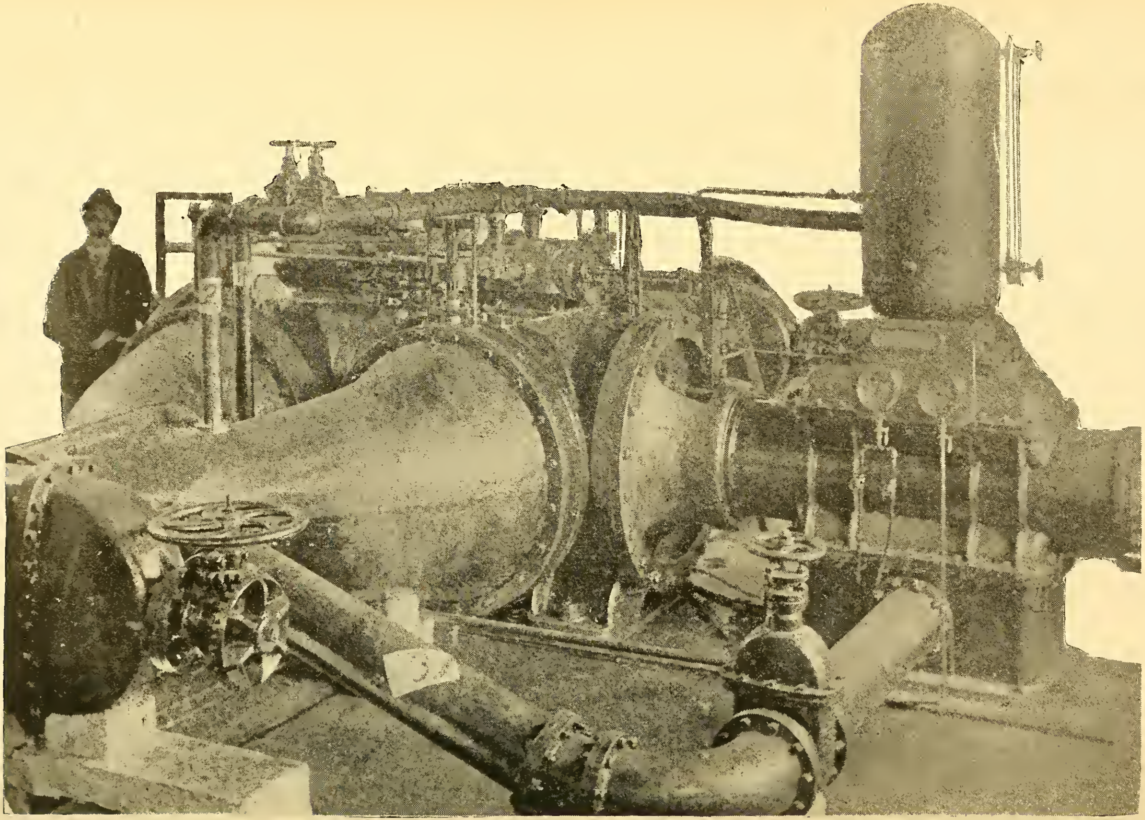


Fig. 1. View of Motor and Pump.

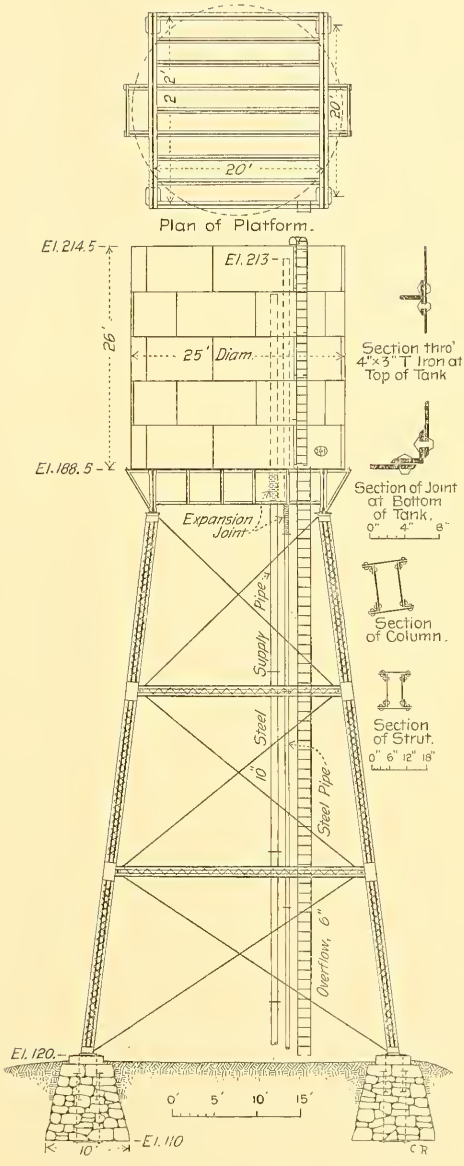


FIG. 2. ELEVATED TANK.

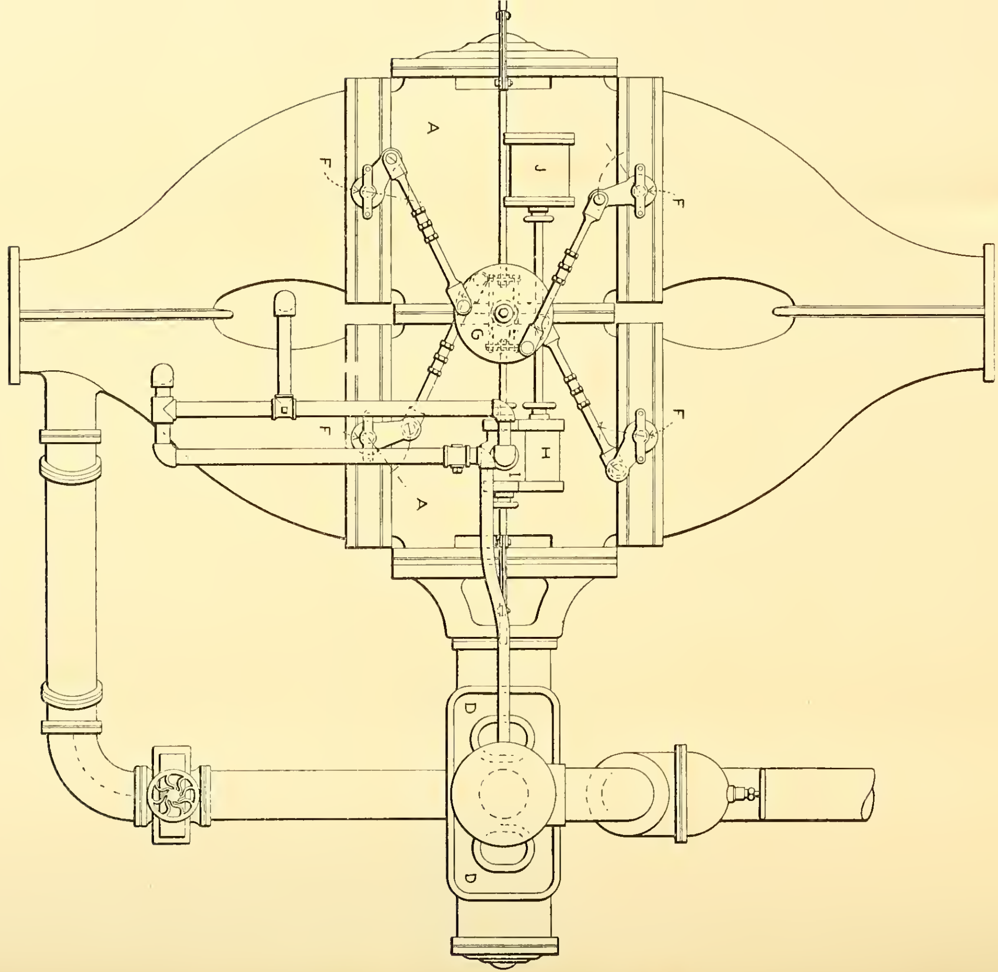


Fig. 3. Plan of Motor and Pump.

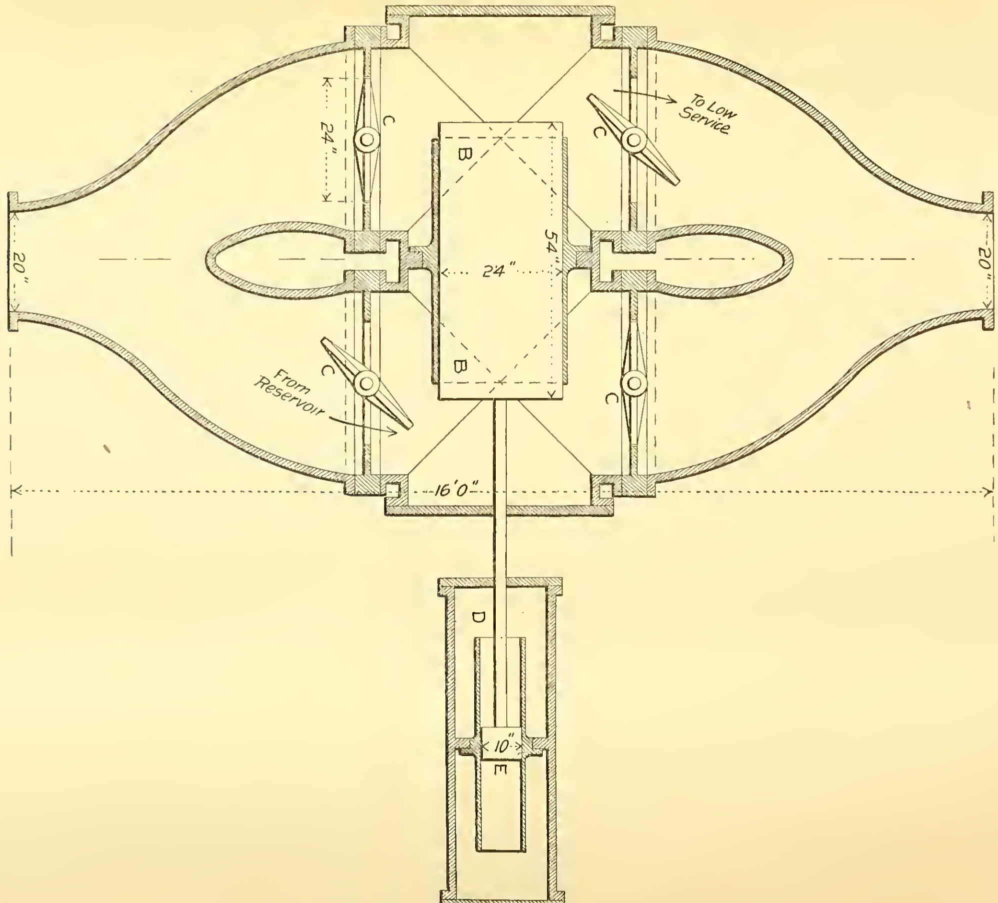


FIG. 4. HORIZONTAL SECTION OF MOTOR AND PUMP.

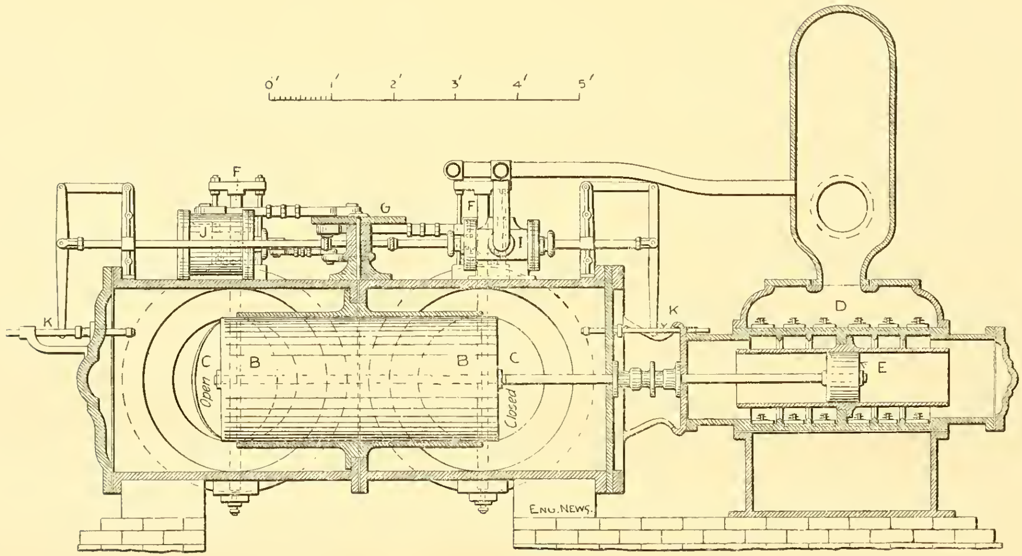


Fig. 5. Longitudinal Section of Motor and Pump.

tened with suitable tie rods and braces. The tower is surmounted by a wrought iron tank 25 feet in diameter and 26 feet high, built up of plates of the following thicknesses : Bottom, $\frac{1}{2}$-in.; first plate, $\frac{3}{8}$-in.; second plate 5-16-in., and third, fourth and fifth plates, $\frac{1}{4}$-in. The vertical seams are double riveted, and the bottom and horizontal seams single riveted, with $\frac{3}{4}$ and $\frac{5}{8}$-in. rivets. A 4x4-in. angle iron is riveted at the bottom and a 4x3 in. T iron near the top. Oak plank hewed to fit the laps are placed between the tank and the girders. All the iron used in the structure is of 45,000 lbs. tensile strength. A suitable iron ladder runs from the ground to the top of the tank, and the tank is provided with a manhole near the bottom. The 10-in. supply and 6-in. overflow pipes are of spiral welded steel. These pipes extend up to the bottom of the tank. They are extended up inside the supply pipe to within 4 feet, and the overflow to within $1\frac{1}{2}$ feet of the top of the tank. These pipes are fastened to the tank with flanges, corrugated copper expansion joints being inserted under the bottom of the tank. The water enters the tank near the top, and by means of a check valve in a branch is drawn from near the bottom. The overflow from the tank returns to the low service supply main. As the overflow pipe is near the supply the constant movement of the water prevents ice adhering to either pipe. All the iron work is thoroughly painted. The capacity of the tank is 90,100 gallons. The height of the tower is $68\frac{1}{2}$ feet, making the entire height of the structure $94\frac{1}{2}$ feet above the pillar blocks, or $214\frac{1}{2}$ feet above mean high tide. The tower and tank were built by the Berlin Iron Bridge company of East Berlin, Conn.

†The engine or motor by which the tank is supplied is situated on the line of the 20-in. supply main, A, and about 500 feet from the tower. It consists of a cast iron cylinder 36 inches in diameter and 8 feet long, set at right angles to the line of the main, containing a hollow, air tight, steel plunger, B, 24 inches in diameter and 54 inches long, which makes a 36-in. stroke.

On each side of the cylinder are two 24-in. butterfly valves, C, which are connected by means of reducing Ys and 20-in. bends with upright 20-in. Y branches (not shown) set in the low service supply main. The pump is situated at the end of the main cylinder, the pump plunger, E, being on the same rod as the motor plunger. The stems, F, of the butterfly valves run up through the casing and are connected by means of arms and rods with a wrist plate, G, on the center of the motor cylinder.

On top of the main cylinder is an auxiliary cylinder, H, 6 inches in diameter, taking water through a cylindrical slide valve, I, moved by a tappet rod, K. On the piston rod of the auxiliary cylinder is a piston working in an air cylinder J, 10 inches in diameter, which acts as a cushion for the valves. This piston rod is connected with the wrist plate above mentioned. The auxiliary cylinder is actuated by water passing from the low service main and exhausting into the air, or may, when the tank is full, take water from the high service pipe and exhaust into the low service mains. In the first instance the amount of water wasted is 1.1 gallons per stroke; in the latter case no water is wasted.

†Reference is made to letters on the accompanying plates.

The supply main runs under the motor, making a by-pass. In the by-pass is a 20-in. check valve which closes by means of a lever, which is weighted so as to offer a resistance of about 5 lbs. per sq. in.

In case of accident to the motor, or if for any reason it should stop at the end of a stroke, the check valve opens and the supply to the city is not interrupted.

The pump is of the usual horizontal plunger pattern. The pump plunger makes the same stroke as the motor plunger, and is 10 inches in diameter.

The action of the motor is as follows : The water passing to the low service district is deflected by means of the check valve into the motor, passing through one of the butterly valves, one on each side being open. The water drives the motor plunger over, which, when near the end of the stroke, moves a tappet, K, which latter reverses the valve of the auxiliary cylinder. The action of the auxiliary piston reverses the butterfly valves, opening two and shutting two, by this means deflecting the water to the other side of the motor plunger, which reverses the above operation; the water, after driving the plunger over, passing on to be used in the low service district.

The motor is in general design an adaptation of the one used at Burlington, Vt., and described before this Association by F. H. Parker,* but is much larger.

It was built by W. H. Lang, Goodhue & Co., of Burlington, Vt., at a cost complete of less than $5,000.00.

The machine is experimental and there are many features which might be improved.

It will be seen that all the water used on the low service is drawn through the motor, a portion of its head or pressure being used to drive the same, and the speed of the motor is thus controlled by this draft. For this reason it was necessary to proportion the motor in the ratio of the draft on the low service to the draft on the high service. This was accomplished approximately, although in three miles of cement lined pipe on the high service the leakage is rather larger than expected. The draft through the motor at present varies from 900,000 to 1,250,000 gallons per day and from 300 to 1,200 gallons per minute On Sundays the draft on the high service is larger than on other days, and as no water is used for manufacturing on the low service on that day, and the speed consequently reduced, the tank is sometimes drawn upon to the extent of about 15,000 gallons.

The speed of the motor varies from 4 to 16 strokes per minute, being about 8 in the night time and 13 in the day time. At about 16 strokes the limit of 5 lbs. loss is reached and the check valve opens. The pressure at the motor is about 35 lbs. changing with the fluctuations in draft and with the level of the reservoir. The loss of head in the passage through the motor varies from 2½ to 4 lbs. The head pumped against varies from 18 to 20 lbs.

It will be observed that for an instant during each stroke, while the valves are changing a passage is open entirely through the motor ; but for this it would be a perfect meter. From observation this loss is estimated at 5 per cent. and the consumption on the low service is calculated on this basis.

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* "Journal of New England Water Works Association," Vol. II., p. 63.

The present consumption on the high service ranges from 13 to 15 per cent. of the amount used in the low service, or about 100,000 to 150,000 gallons per day and the capacity of the pump is a little over 15 per cent. of the water passing through the motor. The water ram due to the stoppage at the end of each stroke is very slight, rarely amounting to 5 lbs.

Tests for efficiency were unsatisfactory. The reason being that the exact quantity of water passing through the motor during the opening of the valves is unknown and that the constant varation in head on the motor and on the pump makes the pressure difficult to determine without very accurate instruments, and further that when running at a quick stroke the valves are reversed before the full stroke is completed. An average of nine tests of six hours each at different times of day and night gave: Number of strokes per minute, 10.74; pressure above motor, 34.62 lbs.; below motor, 31.46 lbs.; difference, 3.16 lbs.; head on pump, 17.8 lbs.

As the pump and motor plungers are on the same rod any shortage in stroke is proportional in both and this factor may be eliminated and both calculated for the full stroke.

Then with the above figures :—

10.74 strokes $\times$ 12.24 = 131.46 gals. pumped per min.
17.8 lbs. = 41 ft. = head on pump.
131.46 $\times$ 41 ft. = 5389.8 ft. gals. work of pump.

10.74 strokes $\times$ 70.5 =	757.17	gals.	per	min.	passing	through		motor.
5 per cent. =	37.85	"	"	"	"	"		valves.
10.74 strokes $\times$ 1.1 =	11.84	"	"	"	"	"		aux. cylinder.
	806.86	"	"	"	consumed.			

3.16 lbs. = 7.3 ft. = head consumed.
806.86 $\times$ 7.3= 5890.08 ft. gals. work of motor.

$$\text{then} \quad \frac{5389.8}{58.90} = 91.5 \text{ per cent. efficiency.}$$

This result is probably too high but is given for want of more reliable data; but its efficiency at the usual speed is over 80 per cent., and is higher when running at slow speed.

The machine has now been in satisfactory operation over two years, working day and night, consuming no fuel and less water than is required to run a coffee mill motor, and requiring attendance but a few minutes every other day. Its economy has been fully demonstrated, and where the conditions under which it works are similar it might be adapted to advantage in other places.

So far as known to the writer, this machine, with the exception of the one at Burlington, Vt., is the only one in existence used for this purpose, although it is somewhat similar in principal to a vertical, single acting engine built in 1842 at Derbyshire, England, to pump water from a mine.

ADDITIONAL DISCUSSION

ON

THE ARRANGEMENT OF HYDRANTS AND WATER PIPES FOR PROTECTION OF A CITY AGAINST FIRE.*

DISCUSSION

BY

WM. R. BILLINGS, TAUNTON, MASS.

It would be well if Mr. Freeman's paper could be put into the hands of every man who is called upon to design a new system of water mains or to enlarge an old system, with orders to read, mark and inwardly digest. The callow graduate or the newly elected commissioner must not suppose that all of his own deficiencies can be made good by a study, be it never so laborious, of Mr. Freeman's clear statements and well sustained conclusions but the trained water works constructor who knows how to make his bricks will find that Mr. Freeman has provided him with the best of straw.

In the appearance of this and a former paper, (see Journal, March 1890) we note an indication that after forty years of experience and experiments in pipe systems, we have reached a stage of careful observation and exact statement. Too often the sizes of distributing mains are determined, by the engineer upon the freight rate theory, that is "all the traffic will bear," or by a water committee governed by the sole desire to spend the smallest possible amount of money, and an opinion having something of the judicial quality of a decision from the court is more than welcome.

Mr. Ellis called attention several years ago to the fact that the work of subduing a disastrous conflagration cannot be hampered by considerations of economy, and so far as the temporary and special fire appliances are concerned no one does insist upon economy in this connection, but the value of a large water main as a fire extinguisher is not immediately evident to the average mind and the two fold office of the water main acting as a distributor and as a concentrator was never so plainly shown as in the paper under consideration.

The great difference between the requirements for distribution and those for concentration is the cause of the real difficulty in designing a pipe system that shall be generous enough for extreme service and not overburdensome for the tax payers. When, to the item of the expense of large pipe is added an unusual demand for money arising from the difficulty of obtaining high grade potable water in large quantities, it does not seem

*See Vol. VII. p. 49.

unreasonable to consider a plan which involves a double system of mains. The money saved by using a convenient and abundant, though impure supply for hydrant and flushing purposes, might in some cases, go a long way in providing a distributing system of small diameters, and the willingness with which people pay for small quantities of spring water for drinking purposes would seem to show that a special supply would find a profitable market in some of the larger and less fortunate cities and towns.

Mr. Freeman ventures to predict that the fire hose of the future will be $2\frac{3}{4}$ inches in diameter. If special appliances are to be provided for handling this larger size, we will agree that the prediction is a safe one, but so long as hose is handled by the present methods we believe that the $2\frac{1}{2}$ inch size will maintain its position. Mr. Freeman admits that 3 inch hose has been found by actual trial to be unwieldly, but his thorough appreciation of the loss due to friction, makes him anxious to believe that we may get beyond $2\frac{1}{2}$ inches if we cannot reach 3 inches and perhaps this wish is father to his thought.

Undoubtedly 250 gallons per minute is the figure upon which one should base his calculations in designing a concentrating system of mains, but there are few systems of today in which the ordinary pressure is sufficient to give the $1\frac{1}{8}$ inch, 45 pound nozzle pressure, 300 feet of hose, 250 gallons stream, to say nothing of small pipe diameters which will render useless any large number of steamers at a given point. A great many towns *are* "running for luck" and except in a few cases like those of Boston and Lynn, luck seems to run with the towns, and until disastrous conflagrations come to be more common, town committees will not find it an easy matter to authorize the expenditure required to meet the safest calculations. They will continue to run for luck, trust to insurance, and then depend upon competition to keep insurance rates within reasonable limits.

During his term of service as superintendent of the Taunton Water Works, the writer made a few crude and incomplete experiments with hose nozzles and a water meter, for the purpose of getting some definite conception of the size and appearance of a 200 gallon stream. The results of these experiments, given in the table below, have little or no value in themselves as they are obviously inaccurate and might easily mislead; but with all their imperfections on their heads they have a certain value for purposes of warning and of illustration.

Case No.	Press. at Hydrant.	Length of $2\frac{1}{2}$ hose.	Size of Nozzle.	Galls. per min. by 2 in. meter.	Distance reached by jet.
1	48+	150	$1\frac{1}{4}$ ring	170	90
2	37	150	$1\frac{1}{4}$ ring	150	80
3	55	50	$\frac{7}{8}$ ring	125	75
4	52	50	$1\frac{5}{16}$ smooth	180	50
5	55	50	$\frac{7}{8}$ ring	Meter	95
6	52	50	$1\frac{5}{16}$ smooth	Removed	75

These figures can warn the young experimenter against broad conclusions from limited data, for though in Case 3, the meter registered 125 gallons per

minute, Mr. Freeman's Table B allows only 119 under these conditions, while in case 4, a 1 5-16 nozzle shows by the meter a smaller discharge than Table B allows for a $1\frac{1}{4}$ inch nozzle under the same conditions, and in both instances Table B is undoubtedly correct. As an illustration, the figures of the table may give additional force to Mr. Freeman's description of himself as "one who vigorously holds that water meters on a pipe supplying automatic sprinklers are a device of the devil," for the obstructive action of the meter is plainly shown in a comparison of Case 3 with Case 5, and of Case 4 with Case 6, when it is seen that in each instance the stream flung itself at least twenty feet farther after the removal of the meter. Finally, the figures of the table bring out, as it seems to the writer, the point that a good fire stream may be had with less than 250 gallons per minute, without bringing into question for a moment, the wisdom of the dictum that it is best to base computations for a pipe system on 250 gallons per minute; or again, a good fire stream is one thing and a basis for computation is another. So far as any impressions remain as to the apparent size of the streams recorded in the table, they are to the effect that the streams of Cases 1 and 2 were thoroughly respectable, that they would have wet down an ordinary dwelling or shop with ease, and that the streams of Cases 4 and 6 were perfect soakers, while the distances to which the streams reached seems to bear out these impressions.

Mr. Freeman shows that 100 pounds pressure at the hydrant is needed to obtain a standard 250 gallon stream through 400 feet of hose. Out of 113 cities and towns in Massachusetts there are but 10 or 12 wherein the ordinary hydrant pressure equals or exceeds 100 pounds. These towns, so happily situated for purposes of water supply are to be found mostly among the hills of Berkshire, and it is to be hoped that here, the high gift of nature has not been marred by obliging the ready stream to exhaust its energy in crowding itself through contracted passages, which may be pardoned in a Venturi meter, but which are the ruin of a concentrating system. A plan that is ample enough to provide the concentration of energy required by Mr. Freeman's calculations will, as a matter of course, be in excess of the requirements of distribution for domestic or manufacturing purposes.

The prime condition then, that we have at call something equivalent to a pressure of 100 pounds at the hydrant, seems to furnish a good starting point from which to enter upon the investigation which shall determine the general character of a public water supply. In the cases ot Cheshire and Hinsdale, Mass., nature solves the problem at the outset by offering a supply at an elevation which gives a pressure ranging from 125 to 150 pounds, and a gravity system follows as a matter of course.

The less fortunate towns must choose between a reservoir, with steam fire engines for extra power, and direct pumping, that is one large fire engine connected with the mains, and in reading Mr. Freeman's figures of the cost of hose and of six inch pipe, one can almost find a new argument for the direct pumping system. There are certainly some advantages in using a conduit 6 inches in diameter, having a life of 50 years rather than one $2\frac{1}{2}$ inches with a life of only 5 or 10 years, the first cost being the same for each.

If a town finds itself without any suitable or convenient location for a reservoir it may find additional reasons for adopting a direct pumping system in Mr. Freeman's paragraphs on "distance and position of hydrants. If financial considerations will permit, why not follow the generous plan outlined therein and place hydrants so frequently, with such liberal supply mains, with such abundant power at the pumping station as to make both steamers and long lines of hose equally unnecessary.

To the question, what is the least number of fire streams with which a town should provide itself Mr. Freeman has given a perfect answer in the following pregnant sentence: "The question, therefore, comes down to getting as near ten streams for a fire district with close lying valuable buildings and having 10,000 inhabitants or less, or as near 30 streams for a city of 100,000 inhabitants as can be had without burdensome expense."

To determine the line of burdensome expense in any given case is not a problem in engineering so much as it is a problem in economics. It is a problem which demands for its solution the ripest judgment, the keenest foresight, the steadiest courage, and the most complete knowledge of the special conditions which the town can command.

DISCUSSION.

BY

G. H. BENZENBERG, CITY ENGINEER, MILWAUKEE, WIS.

The exceedingly interesting and valuable paper of Mr. John R. Freeman leads thought in the direction necessary to the consideration of the proper distribution of mains and hydrants for fire protection, and on account of the great care and study devoted to its preparation, is one of the most valuable papers upon that subject.

Mr. Freeman points out clearly the defect or the common error of many systems, namely: Too small mains and too great distances between fire hydrants, and I wish to add but a few words to emphasize these facts. Economy of force and power apparently does not always receive attention at the hands of water works people, otherwise neither 4 inch hydrants, connection to hydrants nor 4 inch mains used to supply hydrants, would ever be permitted to wantonly waste the energy, carefully created or stored in the works. Greater care would be exercised in proportioning the mains, in taking the elevations into consideration when locating mains and of reinforcing the system by larger feed mains when increased consumption has reduced the pressure and thus prevent the frequent and often justifiable complaints heard in many cities as to inadequacy of supply and pressure when such may frequently be charged only to a positive inattention to proper distribution. Large feed mains should be carried without diminution to the very heart of the town and beyond and along the line of maximum

consumption, so as to deliver volume without sacrifice of pressure on the opposite side of the town as well as on the side entered always with the single view of furnishing a supply equal to the demand of each particular locality, but at a pressure approximating uniformity throughout the entire distribution, excepting as influenced only by the varying elevation of its streets. While this is not always attended to, sometimes for want of funds, but many times for want of study, and therefore much pressure is wasted in the mains, a greater per cent. is lost on account of the scarcity of hydrants, and this fact I wish to impress still further, by particularizing.

Undoubtedly the efficiency of a fire department in battling with a large or fierce and hot fire, greatly depends not only upon the volume, but also many times upon the promptness with which they can concentrate such volume of water upon the fire, with a pressure that will penetrate the flames and deliver the stream almost unbroken upon the burning material; hence the necessity in a direct pressure system of bringing the volume and energy of the water as stored in the reservoir, or as developed at the pumping works, or in case where steamers are used, the volume of water with the energy of the steamer, as close to a fire as possible. The more nearly this can be accomplished, the more perfect are the conditions for successfully fighting fire. Very often would the foreman much prefer to use a $1\frac{1}{4}$ inch or even a $1\frac{3}{8}$ inch nozzle at a hot fire were he sure of the necessary pressure to deliver such stream to where it is needed, but knowing full well that the long line of hose in delivering such volume, would consume too great a percentage of the available pressure to make such stream valuable, he is obliged to direct the use of a $1\frac{1}{8}$ inch or even a 1 inch stream upon the flames with correspondingly less favorable results; hence the necessity of the introduction of modern appliances, as the siamese connections, water towers, stand pipes at large buildings, etc., to recover or save some of the available pressure.

Accepting the general average number of hydrants per mile of pipe as seven, although this in some cities is exceeded and in some doubled, it would place on the most favorable general gridiron system of distribution, the hydrants about 380 feet apart, with not more than six streams available from three hydrants within a limit of 350 feet of a favorably located fire. Assuming in a direct pressure system a hydrant pressure of 75 pounds, this would afford four fair streams through 150 feet length of rubber lined hose with $1\frac{1}{8}$ inch nozzles at a loss of about 24 pounds of pressure in each and two fair streams through 350 feet length of hose with 1 inch nozzles at a loss of about 30 pounds of pressure each on account of friction in the hose. Should the fire be fierce and have obtained a good start, a larger number of streams would be required, several of which ought to be good $1\frac{1}{4}$ inch streams to successfully check it.

Unless the fire could be fought at close quarters, but few additional fair and effective streams could be brought to play upon it. Should $1\frac{1}{4}$ inch streams be used, the loss of pressure would vary from about 30 pounds in this, taken from the nearest hydrants, to a loss of about 37 pounds in four

1 inch streams taken from the fifth and sixth nearest hydrants; or in other words: Nearly one-half of the available pressure at the hydrant would be absorbed by friction; an unwise loss of stored energy. With hydrants, however, placed at but half the above distances apart, and with the fire located at the same place, the loss of pressure in the first case would be but from 12 to 20 pounds, and in the second case but from 15 to 20 pounds, instead of 30 to 37. Or the number of streams in the first case might be increased from 6 to 14 and in the second case from 12 to 26, without any increase in the length of any line of hose; certainly a desirable result, if it can be obtained without any great increase in the percentage of cost. In placing the hydrants 190 feet apart the number would be increased to 21 per each mile of pipe, but as such spacing would not be necessary except in the business or manufacturing districts where all the available pressure is required to combat fires that are most likely to prove disastrous, it would not amount to an increase of more than one-fifth upon the entire distribution, or an average increase of about $2\frac{1}{2}$ or 3 hydrants per mile at an increase of cost of not over $\frac{3}{4}$ to 1 per cent. of the cost of the entire distribution. Would any engineer hesitate to incur that additional expense in any other part of his works if thereby he could increase its efficiency from 25 to 30 per cent? And yet such result in the distribution can be obtained by spacing hydrants but half the distances they generally average apart. Not at the hydrant, but at the nozzle where increased efficiency in either volume or pressure is needed to protect property. Where the water works are owned by the municipality it undoubtedly is a matter of direct economy, for the saving in the purchase and renewal of hose during the lifetime of a good hydrant will more than outweigh the cost of the additional hydrants.

Again, what benefit is derived from a large main with hydrants far apart, when compared with a smaller main, which with hydrants less distance apart, gives better nozzle results, although the friction loss in one may be but $\frac{1}{4}$ that in the other, as in the case of a 16 and a 12 inch main. The cost of the former exceeds that of the latter by from 85 to 90 cents per foot or more than the cost of hydrants placed at the rate of every 50 feet on the 12 inch main. The loss of pressure by friction with a flow of 2000 gallons per minute in the latter is but about $3\frac{1}{2}$ pounds per 1000 feet of pipe more than that in the former, while the loss in each 50 feet of rubber lined $2\frac{1}{2}$ inch hose on a 300 gallon stream is about 10 pounds, so that nearly 30 pounds better nozzle pressure can be obtained without any additional cost by using a 12 inch main with hydrants every 50 feet, all other things being equal, instead of using a 16 inch main with hydrants every 380 feet. I do not wish to be understood as recommending the use of smaller mains, but that the same care should always be taken to extend the efficiency of a system to its very termini, and that in providing an adequate supply and pressure in the mains, almost beneath the very fire that baffles the efforts of the firemen, a system is not perfected, because perhaps not more than half that pressure and volume can be hurled against it.

Wherever direct fire pressure is not supplied, but the steamer is relied upon for the necessary pressure the same objections to long lines of hose

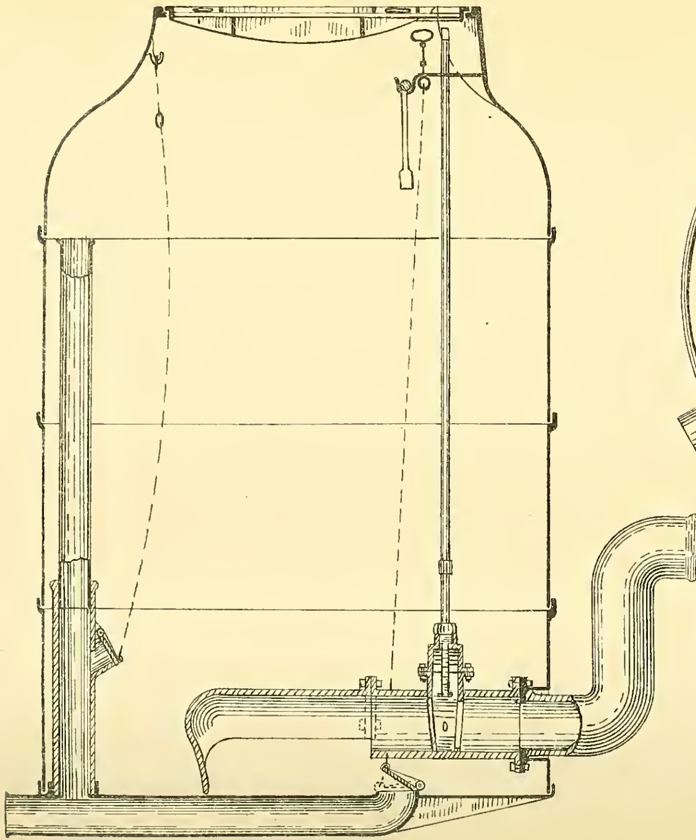
holds good, and such should be avoided as much as possible. In such cities the effort should be to supply the volume of water near any possible fire so as to permit the grouping of a large number of engines as close to a fire as possible. This can be accomplished by the use of Lowry hydrants, although I believe better results can be realized with fire cisterns into which the full volume of the main may be delivered and around which five to six first-class steamers can be grouped, thus enabling the concentrated delivery of the full volume of the main with almost the entire energy of the engine; nearly the most perfect conditions necessary to overcoming a fire. With such cisterns located in the center of each block from 20 to 24 steamers throwing from 40 to 48 $1\frac{1}{4}$ inch streams can be grouped around a square. From personal observations I find that much better time is made by the department in getting good streams from the cistern, than when the steamer is connected with a hydrant, and the men also seem to prefer placing their engines at such cisterns. The annexed diagram shows the style of fire cisterns now being used in Milwaukee. The entire cistern is made of iron, the rings being cemented together at the joints. The water pipe is 6 inch diameter and in its extension in the well beyond the valve, terminates in a section which is open for the lower third of its circumference and rounded at its end, so as to divert the flow downward without a break in the stream. Especially successful work, because of the almost perfect conditions, has been done by the fire department with the aid of these cisterns, of which some 90 have been constructed in this city during the past two years.

Another aid toward fighting fire has been introduced here during the past year which will be still further extended next year. The effectiveness of the very powerful fire boat has been limited by the great loss of pressure through extreme lengths of lines of hose. To utilize the service of the boat therefore at long distances from the docks, a line of 8 inch pipe with numerous hydrants has been extended from the dock to a manufacturing center some 1500 feet distant. The boat connects its three lines of $3\frac{1}{2}$ inch hose by a siamese connection at the dock with the pipe line and is at once ready to furnish five or six good $1\frac{1}{4}$ inch streams at the end of such pipe line with no greater loss of head than that of one such stream through 150 feet length of hose. The hydrants used are furnished with independent valves at each hose connection, but have no valves at the base, the pipe is kept full of water by a check valve at the dock, except during the winter when the pipe is drained on account of the same being but 2 to 3 feet below the surface.

Following the timely suggestion of Mr. Freeman as to the collection of statistics regarding large fires, I will submit the following with reference to the late large fire in our city.

The fire started at about 5.30 p. m. October 28th, and covered an area, before it had finished its work, of $66\frac{1}{2}$ acres. Half of the wholesale business, shipping interests and manufactories, besides hundreds of dwellings were hazarded by this fire. The total loss was about four and one-half million

SECTION



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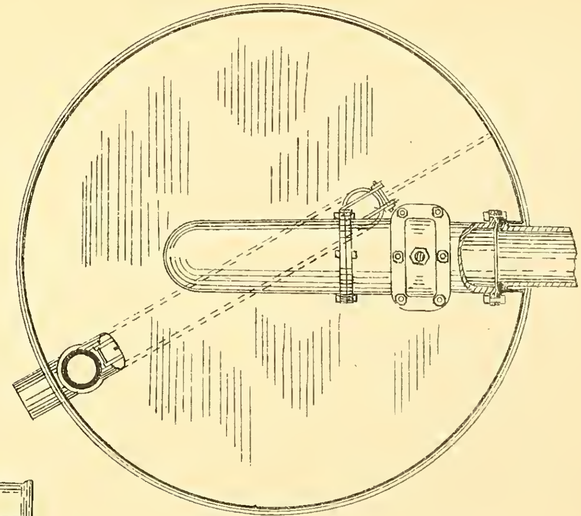

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dollars. The maximum rate of fire over ordinary draught from water works system was about 12,600 gallons per minute. To this may be added about 8,600 gallons per minute delivered from the river direct. The maximum number of streams at work at one time and supplied from the water works system was 42, in addition to which there were 24 streams supplied from the river. The fire lasted about seven hours before it was at all controlled or checked and eighteen hours before you might say it was nearly extinguished. The total fire draught was about 8,750,000 gallons supplied from the water works system and about 7,650,000 taken from the river. The method of supply of the fire streams was from steamers supplied from fire cisterns and hydrants, and also from a number of steamers and the fire boat, taking its supply from the river and it has been generally conceded that in the most valuable wholesale district the fire was prevented from spreading still further because the steamers were concentrated at fire cisterns and could throw forth their combined streams through the largest sized nozzles upon the very hottest part of the fire, and I have come to the same conclusion from personal observation of the various streams and their effectiveness both at that fire and many of our very hot fires that we have had in the city since that day.

DISCUSSION

BY

Walter H. Richards, Superintendent, New London, Conn.

To sum up the conclusions of Mr. Freeman's paper, the ideal works in a city of say 20,000 inhabitants, should be able to supply 8 to 15 streams of 250 gallons per minute each, with a hydrant pressure of 100 pounds. Hydrants should be from 250 to 400 feet apart and no mains should be less than 6 inches in diameter.

While we must all admit that it is desirable and necessary to approach this standard as nearly as possible the question arises can this ideal be reached, keeping in mind that the first object in building water works is a sanitary one, to furnish pure, potable water. This consideration should never be subordinated to considerations of fire protection and I think it could be shown to be poor economy to do so even if looked at only from a financial standpoint. Many cities must soon make large expenditures for the sanitary improvement of their water supplies, and the question of fire protection must be considered afterwards. It may even be that a pure drinking water will reach so high a value as to preclude its use for extinguishing fires.

One hundred pounds pressure at the hydrant is found only in rare cases. In the majority of cities the deficiency must be supplied by steamers and this is probably the most economical way except in cities having little variation in contour.

Mr. Brackett shows that none of the larger cities approach this ideal standard and a moment's thought on the part of any superintendent will show that in a majority of cases, to remodel *at once* a water works system built 15 or 20 years ago, so as to fulfill these conditions would be beyond the resources of the department.

Some increase in capacity could be attained in other ways than the enlargement of mains and increase in pressure, for instance by preventing corrosion and retaining the smoothness of the interior surface, by eliminating the sharp corners in gates, hydrants and branches, and preventing undue waste and consequent loss of pressure.

Mr. Brackett advocates hydrants with four nozzles, two 2½ inch and two 4 inch, yet New York and Brooklyn manage very considerable fires with one 2½ inch nozzle, under a few pounds pressure. The cisterns proposed by Mr. Benzenberg would seem to be a cheaper way to accomplish the desired concentration. The tendency seems to be towards a constant increase in the capacity and consequently in the cost of a water works plant for the purpose of fire protection. May it not be that the increased efficiency of the fire department would help matters and can't the insurance companies run some risk?

In planning new work the conditions proposed, excepting the pressure, can be attained usually with economy, but the work of renewing old work must for economic reasons proceed slowly, but should always *aim* at and so ultimately attain to the conditions desired. So far as the pressure of 100 pounds at the hydrant is concerned it is doubtful if that can ever be had in a majority of cases.

DISCUSSION

BY

JOHN R. FREEMAN, CIVIL ENGINEER, BOSTON, MASS.

I have taken great pleasure in reading the contributions to this growing subject of "Fire Protection" from men so experienced in the active management of water works as Mr. Benzenberg, Mr. Richards and Mr. Billings.

In all such questions much depends on the point of view, and though I was morally certain of the truth of my deductions, I had almost feared that from my long work in arguing for increased protection, I might have been led to overrate some of the possibilities; and as my position or statements were somewhat advanced beyond the line heretofore generally occupied, I put them forth with some timidity.

I value exceedingly the appreciative words of Mr. Benzenberg, city engineer of Milwaukee, and Mr. Billings, former superintendent of Taunton, and am much pleased that they concur so fully in the views which I ventured to express.

In the remarks of Mr. Billings, there is but one paragraph with which I would take serious issue—this is the third paragraph, wherein he quotes a statement of Mr. Ellis' to the effect "that the work of subduing a conflagration cannot be hampered by consideratiou of economy."

Now it has been my almost daily experience that fire protection *is hampered* by questions of economy, and a large part of my study for some years past has been to find out just where *true economy* comes in.

It is my belief that *true economy* would burn the patterns for 4-way hydrants and would never install a 2-way hydrant with less than a 5-in. gate.

(It takes but a very few pounds more of cast iron to surround a 5-in. hole than for a 4-in. and the power to conduct water is about twice as great.)

True economy would not throw away a full half of the head which your reservoir produces in useless friction in trying to save the extra expense involved in hydrants 250 feet apart instead of 750 feet apart; and then spend in a moderate sized city a thousand dollars a year extra for hose renewals entailed by the greater lengths of hose laid and used.

True economy will recognize, as Mr. Billings does, that a 6-in. imperishable conduit of cast iron is to be preferred to a $2\frac{1}{2}$-in. conduit of cotton, lined with rubber (possibly adulterated) when the former costs less, foot for foot, than does the latter.

True economy will some day adapt a four-ton steam fire engine to expend most of its energy in projecting three streams of large volume on to the fire,

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Page 161, line 21, for "4-way hydrants" read "4-*inch* hydrants."

instead of as now, merely satisfying the engine men by showing 150 lbs. on the water gauge while one stream frets itself away through 700 or 800 feet of hose and issues with a pressure of 30 lbs.—absolutely wasting more than half of its energy in useless and unnecessary friction.

In reading Mr. Benzenberg's discussion, I am much interested in his account of the isolated cisterns which he describes.

I have myself not been specially favorable to this expedient and had supposed that the expense involved would be greater than that from an adequate pipe system ; but I am very glad to learn of the way another engineer has attacked the problem, and whenever again I visit the "Cream City," this will be a detail on which still more light and experience will be earnestly sought by me.

I thank Mr. Benzenberg for his statements of the per cent. of increased cost involved in developing the extra efficiency for fire protection. This puts the matter in the most practical light possible and I can only echo his sentiments and pass them along to my good friend Richards. "How can any engineer hesitate to incur an additional expense of one per cent. on the cost of water works, when he can thereby increase its efficiency for fire protection 25 per cent.?"

Turning now to Mr. Richards' remarks I most heartily concur in the view that with established works we often have got to go slow and for a long time rest content to take things about as we find them.

But as works grow older and prosper, as bonded indebtedness is retired, we can always little by little work toward our ideal and what ever we do should be done with a comprehensive system—*an ideal system* if you choose—clearly in mind.

As to the suggestion that "the first object of water works is to furnish pure potable water;" no doubt that is the grand object, but that the fire protection question is sometimes first in the hearts of his countrymen is seen when we recall the fact that in our small New England communities, it is the "Fire District" which time and time again has been first in the field with its water pipes for fire protection.

Marblehead, Andover, Easthampton and some dozens of other New England towns had their water works put in in the first instance, almost solely *for fire protection.* The corporations at Lowell, Lawrence and Manchester had put in extensive supplies with large reservoirs, chiefly for fire protection, nearly two score years before a general supply for domestic purposes was undertaken in either city.

Both fire protection and domestic supply should have their fair share of consideration.

I may be pardoned for some illustrations as to how fire protection pays.

Take cotton mills : Forty years ago insurance on the ordinary cotton mill not protected by special appliances, cost from 2 per cent. to 2½ per cent. per year, and the chief insurance authorities of the times said "there was no profitable way to take the rate cheaper."

A leading manufacturer, and judged by his own day and generation, a bold and original engineer, thought *fire protection would pay*, and after thinking the problem out, started an insurance company on the principle of encouraging pipes, pumps and hydrants, and the cotton mill of today, though having larger undivided floor areas and more rapid processes, and many new sources of hazard, secures if properly protected by pumps, sprinklers, etc., insurance at just one-tenth part of the old time cost.

Take rubber factories: Ten years ago the insurance companies said: You cannot insure these for less than from 3 per cent. to 5 per cent. a year, and even at this rate they are a poor, hazardous business.

Then came some men who said they would see what could be done to make these same rubber factories safer, by installing hose, fire pumps, automatic sprinklers, etc. Wherever they could find a place to put a sprinkler, there they put one in; and though their private fire apparatus of one kind and another sometimes cost $10,000 for a single large factory, they boldly spent their money. What is the result? Not a single destructive fire for eight years in one of the many factories so protected; and their insurance now costs from one-fifth to one-eighth of what it did ten years ago.

So it is, though in a much smaller degree, in the protection of a city. Well considered engineering, careful planning in proportioning the pipe system with frequent cross connections so that not merely *distribution* but also *concentration* can be obtained, will pay most magnificent interest on its cost.

Mr. Richards regards a pressure of 100 lbs. with a possible volume so great as I have specified, as almost an unattainable ideal. I cannot agree with him; I believe it is time for us to turn our faces toward the sunrise and do our part towards stopping a waste like that of $146,000,000 for the actual loss by fire in the United States in the year 1892, or the $155,000,000 which is the projected loss from the record thus far for the year 1893.

Although 100 lbs. is mentioned in my paper as *the ideal*, 80 lbs. may be so managed as to afford excellent protection in case a greater pressure is not obtainable without undue expense.

With the mains generous in size and frequently "grid-ironed" across, and with hydrants set not more than 250 feet apart, a protection would be afforded much better than that which the average city gets from its equipments of steamers; and even with 70 lbs. of reservoir pressure, if the post hydrants be all put in with 6-in. barrels and 6-in. gates; if the corners of the branches and passageways be all studiously rounded off so as to minimize the friction loss, if then hose $2\frac{3}{4}$-in. in diameter be adopted, even though coupled up with couplings of the same $2\frac{1}{2}$-in. bore, as in use today, and with the hydrants zigzagged along the street 200 feet apart, there can instantly be obtained on any part of the territory so equipped, a degree of protection, I venture to say without fear of proof to the contrary, which would be better than anything that our average city of 50,000 inhabitants realizes today from its equipment of say four first-class steam fire engines.

Mr. Richards cites the single-nozzle low-pressure hydrants of Brooklyn and New York as an argument for tolerating certain relics of a by-gone period; but I don't think that any insurance man who has followed the course of large fires in the city of Brooklyn for the few years past would send one there to learn fire protection unless it be to learn "how not to do it."

In New York a kind providence and a remarkably well organized fire department has thus far put off the evil day. Their success is due to good luck, not to good fire protection engineering. This I believe is the feeling of every one who is familiar with the enormous hazards and the inadequate safeguards of that city.

The nervousness of the insurance managers on this point may be seen by the organizing at an expense which it has been estimated might reach $100,000 per year, of a very elaborate system of inspections on behalf of the underwriters with a view to decreasing the chance of a fire once getting well under way in the congested district of New York.

If the supply be from a reservoir then fire protection may add to the cost by demanding a greater elevation and will add to the size of the diverging branches of the pipe system and may require double or treble the number of hydrants now common. If the service be by direct pumping then often treble the pump capacity for domestic service may be called for.

The total annual amount of water needed for fire protection is so very small as to be utterly insignificant in comparison with the annual or monthly draft for other purposes.

Considerations of fire protection do not burden one seriously therefore by adding much to the number of million gallons of water per day which must be found.

Water for fire protection is like the Texan's pistol, "when you want it, you want it like h—l," but you don't need to use it for a great while at a time.

SELECTION OF SANDS FOR A FILTER.

BY

Mr. Allen Hazen, Chemist, Experiment Station, Lawrence, Mass.

I was asked some months ago by Mr. Mills, the consulting engineer building the Lawrence filter, to take charge of getting out the sand for the filter, and there were some problems which came up, which I thought perhaps would interest you.

There were a number of things to be thought of. In the first place the size of the sand to be used for filtration had to be determined. The coarser the sand, the larger the open spaces, the less the friction of the water, the more water can be made to pass the sand, and the less is the effect of the filtration. In order to make the filtration effective, to take out the bacteria and suspended matters, it is necessary to have a sand that is fine enough to do the work. On the other hand if the sand is too fine, the frictional resistance of the sand is very greatly increased, the amount of water which will pass is reduced, and it is not a commercial success; you cannot get water enough from the limited area. So we have to strike a mean, to get a sand which is fine enough on the one hand to take out the bacteria from a water which contains sewage, as the Merrimac river does, carrying the germs of disease, to take out the bacteria and make the effluent free from germs; and on the other hand, it must be coarse enough so that we can get the water through to make it a commercial success. So the question of the size of the sand to be used required considerable attention.

There are filters in use abroad in a great many cities, but unfortunately we could get data in regard to the size of the sand used in only one case, that is at the city of Berlin. We had some information with regard to the character of the sand used there, but it was not entirely satisfactory, and we depended mainly, in determining the size, upon the experiments which have been made at the Lawrence experiment station.

Those experiments were with sands ranging from the fine river silt with its particles three hundredths of a millimeter in diameter up to coarse sands and fine gravels, covering the whole range. And we decided upon a certain grade of sand, samples of which I have here in these bottles. We had to make a definition of the size of the sand; this is marked "50." That means that with a layer of sand say one foot thick and under one foot head or pressure, just as much head as the depth of the sand, and with all the pores of the sand full of water, and with no deposit on the top, so that there is simply the friction of the sand and not of any surface covering included, and at a temperature of 50°, water will run through the sand at the rate of 50 million gallons per acre daily. The amount of water which it is proposed to filter is

of course, very much smaller than that, being one and one-half or two million gallons per acre daily. But it is necessary to have the sand with a capacity very much larger than is to be filtered, because in the first place, the available head is very much less than the depth of the sand. Now, this sand in a filter 60 inches deep, if the loss of head is 60 inches, and it is all clean, will let through water at the rate of 50 million gallons per acre daily. But if we have only 6 inches loss of head, and that would be more nearly as we should expect to run the filter, one-tenth as much loss of head as the depth of sand, it would let water through only at the rate of 5 million gallons per acre daily. The amount of water which will pass is inversely proportional to the head, the depth of sand remaining the same.

As the more or less muddy river water comes onto the sand, the silt will fill up the interstices to some extent so that the quantity of water which will pass after a time is very much less than it is at the beginning and the sand has to be much coarser on that account. If it were just the right size at first to let through the calculated amount of water it would very soon silt up so that almost nothing could pass. The size selected, as we have found by experiment, with the head which is available, will let enough water through the sand so that the quantity of water required by the city can be filtered; and on the other hand it is fine enough to do the work required.

The problem of getting a large quantity of sand, some 20,000 yards as required, only a part of which has been gotten out at the present time, and getting it all of the same size, is quite a problem. If the sand in different parts of the filter is of different degrees of fineness, has different coefficients of friction, say the sand is twice as fine in one side of the filter as the sand in another place, the frictional resistance varying as the square of the size of the sand, the coarse sand would let through four times as much water as the fine sand. That would practically mean that the part of the filter which was made of coarse sand would let the water through so fast that the filter would not do its work, and the fine sand wouldn't do anything at all. So it is necessary to have the sand, at least in that part of the filter which acts as the unit, all of the same grade.

The sand in the bank is a glacial deposit and changes its character some times every few feet; sometimes we could get layers of the right grade extending for a considerable distance, but ordinarily it is changing all the time. And we had to watch the men getting it out very closely to prevent them from mixing in the fine sand. The man who had charge of the shoveling, was a man who had been screening sand all his life, that was his business, but he had been getting out sand for use in mortar and cement, and the problem there is entirely different. In getting out sand for mortar, it is the largest particles that count; a sand is wanted with the particles finer than a certain size, and they don't care about the fine particles. But in filtration it is the finest particles that count, and if a fine sand and coarse sand are mixed the fine particles will fill the spaces between the larger particles so that the water has to go around the comparatively large grains and through the fine sand; so it is a fact that if two sands, one being twice as coarse as the other, are mixed in equal parts, or any other proportion within reasonable limits, the character

of the mixture is nearly the character of the finest sand. In examining sands we have to put all our attention upon the finest particles; the coarse particles do not count at all for filtration or not to anything like the extent that the fine particles do. The men used to tell me when I insisted upon their taking out fine layers, that it would make no difference, that we could not tell the difference when it got mixed up with the rest. But it did make a difference and we could tell by the examination, if they were neglecting their work, and we had to watch them very closely.

The size of the sand is determined by calculations from siftings and micrometer measurements of the particles of sand. We find the frictional resistance is inversely proportional to the square of the size of the smaller sand grains, and we have made experiments at the Lawrence experiment station so that from an examination of sand and micrometer measurements we can predict approximately the frictional resistance without making actual frictional tests which would require more time than we are able to give to the hundreds of samples which need to be examined. But even this examination required to be made in the laboratory and could not conveniently be done in less than half a day, and so for the use of the men in deciding on the ground whether a sand would do or not I found it necessary to use another contrivance. For this I found most useful a cylinder of tin, 6 inches high and 3 inches in diameter with a wire bottom. The foreman who made the test, filling this half full of sand and packing it down closely, would fill the cylinder with water and then observe the time it took the water to pass through the sand. The coarser the sand the quicker the water would go down. He would make in this way, probably, 30 to 50 tests a day of the sand as it was being gotten out, or more than that if necessary. Of a certain proportion of those, duplicate samples were taken in eight ounce bottles which were sent to me at the laboratory and complete examinations made. In that way I could compare my results with his and tell him the time limits for the sand for the next day. The time it takes the water to go through the sand depends upon how closely the sand is packed, (there is a personal equation) and it also depends upon the temperature. The higher the temperature of the water the quicker it will go through. So the temperature of the water was taken each time and a correction applied. The size of this correction is rather surprising at first. A sand will pass twice as much water, other conditions being equal, at summer heat, 76°, as it will at the winter temperature of 32°, so the importance of applying the correction is very apparent.

The sand has to be under-drained by gravel. You understand the general scheme of the filter.* It is comparatively level, in some places there is something of a slope, but there is a broad bed of sand which is supported by gravel. The water passes down through the sand, and then the gravel takes the water rapidly from the point where it comes through to the under-drains. We have gotten out something like a thousand yards of gravel of different sizes to support this sand. The gravel immediately under the sand is comparatively fine, so fine that the sand cannot work into its pores, and then grad-

*In Prof. Sedgwick's paper this volume, page 103, details are given in regard to many European filters.

ually grows coarser to the under-drains. To get out gravel of the different sizes we started with hand screening, but that was very expensive, shoveling it over by hand each time. And as the material was coming out of the side of a bank some 40 feet high and all had to come down, it occurred to me that we might put screens in position and make the material screen itself in coming down. And so we built, with the help of Mr. Salisbury, a screening appliance of which I have some photographs. The mixed material running down the chute is sent over a screen with inch and a half meshes and down into a bin; all sand going through the screen is sent over another screen three-quarters of an inch, then three-eighths and three-sixteenths, all the sand coming out at the bottom and the different sizes of gravel piling themselves up in bins ready to be carted off. In that way we reduced the cost of screening the gravel to probably not more than half what it had been by hand screening.

The sands in these bottles (exhibiting specimens) are the standard sizes, having the frictional resistance selected by Mr. Mills. One of them is a little coarser than the other ; they are marked "50" and "70," those figures representing the relative amounts of water which the sands will pass under comparable conditions. And in this bottle I have put another sand which is more mixed. It has the same co-efficient of friction as this sand. They are each of them marked "50," but one of them contains more coarse particles than the other. This sand the men who have been taking out the sand would invariably consider a great deal coarser than this. We could not get them to look at the sands in such a way as to determine the sizes from their appearance. These two sands are actually of the same effective size for filtration, but the apparent sizes are quite different. (Applause.)

LIGHT FOR NIGHT WORK.

BY

Edwin P. Gardner. Supt., Norwich, Conn.

When one has outside work to do at night, the comfort and efficiency of the men, the measure of success attending his labor and the cost of the job, depend largely upon the amount of artificial light he is able to throw upon the work and its surroundings. The electric light answers the purpose admirably when it can be obtained, but it is not always available.

The use of kerosene lanterns, black lamps or torches is very unsatisfactory. A light for this purpose should be portable, reliable, efficient, easily managed, economical and durable.

In conversing with our members I find there are some who do not know

that such a light has been invented and can be easily obtained. This is the excuse for this paper.

During the past eighteen months I have used the Wells light and have found it to answer the above requirements admirably.

It consists of a galvanized steel tank, about 18 by 24 inches, into the top of which is inserted and fastened an air pump. From the top rises a 1 inch stand pipe, attached to the base of which is a pressure gauge and a peculiarly constructed valve and strainer. Into the top of this stand pipe is inserted a burner, formed principally by a series of tubes arranged around a hollow square and terminating at the back end in a jet about 1-64 of an inch in diameter, directly in front of which is a hollow iron cone. Immediately under the burner and fastened to it is an iron dish or cup.

Its operation is as follows: First fill the tank about three-fourths full with kerosene oil and by means of the air pump, force air into the tank until the gauge shows a pressure of 20 to 25 pounds. Then fill the dish or cup, under the burner, with kerosene oil and place over it the temporary sheet iron chimney or cover. Light the oil in the cup and the flame will heat the tubes. When sufficiently heated open the valve at base of stand pipe and the pressure in the tank will force oil up said pipe and through the tubes, where the heat will change it into gas, which will escape through the jet and hollow cone and be ignited in the hollow square formed by the tubes, producing a flame from 24 to 30 inches long, giving a pure white light. The flame in passing through the hollow square keeps the tubes hot, producing a continuous stream of gas, so long as there is oil and pressure in the tank. By means of the air pump the pressure may be kept up and the tank filled with oil while the light is burning.

The consumption of oil is about one gallon per hour. I have used it principally while repairing breaks in cement water pipe. It illuminates a large area, so that one can readily find the small tools needed and can watch the banks of the ditch, to note any indications of caving. Ordinary print can easily be read when standing 100 feet from the burner.

I have used it all night with the thermometer at 6° and again at 75°; when the air was still and when the wind was blowing 25 miles per hour; in clear weather and in a severe rain storm.

By placing a short section of oil hose between the stand pipe and burner, the latter may be lowered into the ditch, raised up on a platform or hung up on a pole. In this way it may be used for melting lead or heating as well as lighting.

I have also used it for melting out lead joints in iron pipe. By means of the oil hose referred to above, the flame can be directed against the lead and with the aid of a blow pipe, connected to a stop in the top of the tank with rubber tubing, I could easily melt the lead. Within ten minutes after the lead was melted out I could handle the pipe with bare hands. The pipe was left in good condition to use again, for the coating was not destroyed as it is when the lead is melted out by fire.

In this work, however, I met with two difficulties. First. To keep up the pressure in the tank with the air pump, for both the burner and blow pipe.

I think this can be overcome by having two air pumps in the tank.

Second. The tendency of the blow pipe to disintegrate and fill up the orifice, in consequence of the intense heat to which it was subjected.

Perhaps this can be overcome by using a platinum or lava tip. Further experiments are needed in this direction before definite results can be given.

DISCUSSION.

Mr Nevons. What is the cost of the light?

Mr. Gardner. It costs $100.

Mr. Sherman. I would say we have been using five of these lights in our foundry for some two months, and all the gentleman claims for it is true, with the exception, that instead of a consumption of one gallon per hour, we have found it about a gallon and a quarter per hour of oil which costs about 5 cents a gallon.

Mr. Gardner. Some nights we have used a gallon and a quarter. It depends upon the length of the flame produced.

Mr. Gould. I should like to inquire how large a pipe you have burned out with it?

Mr. Gardner. The only time I have put it into practical operation in the ditch was on a 10-inch joint. One night I had a 10-inch joint to melt out for the purpose of extending the pipe, and I think I used just an hour on the job, but a considerable part of that time was taken up in clearing the orifice in the blow pipe with a pin, we had to keep stopping and cleaning it out, in consequence of its being an iron blow pipe. And then as I was anxious that the experiment should be a success, because there were a hundred or more people looking on, I spent more time than was necessary. From the fact that my eyes were not protected with colored glasses as they should have been, I found I had not only melted out the lead but had burned out all the gasket, which, of course, was not necessary. I expected to find a little lead at the inside of the joint, but it was completely gone, gasket and all, which shows that I kept the flame on longer than was necessary to remove the lead. After the first few moments of its use I became light-blinded, so I could not distinguish readily when I had finished melting the lead in any one particular spot.

Mr. Gould. I have tried to burn out a 40-inch joint, but found life was too short for the work. I used up one forenoon and got about six inches.

Mr. Gardner. I found no trouble with the 10-inch joint. I couldn't very well have melted it out by fire, because there was a 4-inch gas pipe running diagonally over the joint, and I wouldn't have dared to have built a fire. But with this light I succeeded in melting it out nicely.

EXPERIENCE WITH CEMENT LINED PIPES.

BY

John C. Haskell, Superintendent, Lynn, Mass.

Although it may seem that any reference to cement lined pipes is unnecessary and that no city or town would use these pipes in the construction of new works, still when we are requested to contribute experience papers to this association some of the superintendents in the cities where cement lined pipes are used may have sufficient experience to furnish material for several papers.

The experience of the city of Lynn with bursts in this kind of pipe is what I will talk about today.

From the first introduction of water in 1871 up to 1876, 48 miles of this pipe were laid. From that time additions were made yearly until 1887, when we had 82 miles of cement lined pipe; since that time no new work has been added. We can give an experience derived from 48 miles of pipe in use since 1876 together with additions averaging about 3 miles per year for 11 years, since which time 5 miles have been replaced with cast iron.

Previous to 1876 we have no record of the bursts, since then they have occurred from year to year in the following number:

1876, 95; 1877, 79; 1878, 79; 1879, 102; 1880, 121; 1881, 103; 1882, 75; 1883, 92; 1884, 84; 1885, 105; 1886, 86; 1887, 110; 1888, 79; 1889, 106; 1890, 136; 1891, 136; 1892, 133.

These were in pipes from 4-in. to 16-in. in size.

This number of bursts means a varied experience, in some cases a heavy damage to property amounting, in one instance, to over $10,000, in others to a serious interference to business by depriving boilers of water and thus shutting down the factories run by power. In all cases an expense for repairs and a risk of fire occurring in the district deprived of water when the loss of only one hydrant might cause much delay to the firemen. The bursts give no warning. In one instance occurring while a man was standing over the pipe which had been uncovered for a service connection. Sometimes several occur in different sections of the city at nearly the same time and during the past year two were reported at once situated over two miles apart. The greatest number of sections I have had deprived of water at one time is six.

During the summer the water generally comes to the surface directly over the leak and runs down the gutters thus showing the location of the leak. In the winter with several feet of frost in the ground the water follows a course where it meets the least resistance. If a sewer connection has been made at any dwelling in that vicinity it follows the line of the

refilled trench and makes its first appearance in the cellar of the building and usually with sufficient noise to wake up the sleepers. On these occasions the superintendent has an opportunity to exercise his tact in adjusting damages which I find can be done satisfactorily at the time. In almost all instances, a large proportion of the bursts occur in the night at the time when our pressure is at its height. During the past year an additional 20-in. pipe for fire purposes was laid, connecting our present reservoir with the centre of the city. On the completion of the work the gate was opened raising the pressure on the recording gauge from 60 to 62 lbs

While it would seem that such a slight increase in pressure would not cause any perceptible increase in the number of bursts, we had 6 that night and within five days a total of 19.

No farther use has been made of this main but in case of a large conflagration it is ready for use. To reduce the risk of damage as far as possible and to repair all bursts without delay we always keep, through the day, a man in the stable connected with the office of the Water Department who is never absent except during the time taken to shut off a burst and return. In the night two men are kept in readiness, a wagon provided with lighted lanterns, a book containing a diagram of each section and all gates, and the necessary tools to be used. As soon as a burst is reported, no time is lost until the gates are closed. The time when the burst is reported, when the section is shut off, and when the water is turned on is recorded. In many cases the section is closed within ten minutes after receiving the report, the burst repaired and water turned on within three hours. We have had three bursts during one night in the business section of the city and all repaired and water on before 6 o'clock in the morning.

One morning during the past year the Edson recording gauge indicated a loss of pressure of about seven pounds occuring the night before just after 10. As no burst had been reported and nine hours had passed since it occurred it was evident that it was situated at some point where the water could escape without being observed. As the brooks furnish the best channels for the escape of water unperceived, men were sent to examine the culverts of all streets to see if there was any increase in the flow below the culverts and to all the sewers.

As we have 109 miles of pipe, 77 of which is cement lined on which to find the burst, I divided it into nearly equal sections by closing fourteen gates, the pressure showed which section contained the leak. This division was continued until the section included one street, 1750 feet in length with three cross streets, and closing the gate on one of these cross streets the flow of water through the pipe showed the leak to be on that street and as there was an abandoned culvert running through the long street under which the pipe from the cross street ran, we went there and found the burst. On excavation it was found that the pipe was broken entirely off, one end lying below the other. It was probably broken by the covering stone over the culvert falling on the pipe which must have been undermined by the flow of water. At this time there was three feet of frost in the ground which prevented the water coming to the surface.

The burst was found in a 4-in. pipe, seven feet from its connection with a 6-in. pipe and 500 feet from a 12-in. About four hours was lost in finding it and three hours for repairs before the water was turned on.

The intention of the Water Board is to replace the cement lined pipe with cast iron in all business streets and in residential streets whenever the cost for repairs nearly approaches the interest on the cost of relaying.

DISCUSSION.

Mr. Jones. The gentleman speaks of having had so many bursts. I would like to ask him how many *leaks* he had.

Mr. Haskell. In our 16-in. pipe we had quite a number of what we called simply leaks, but if they were not repaired right off, almost as soon as they showed, they would have resulted in a burst. The only point where I would draw a line would be where the leak is due, perhaps, to a spread of the iron, and not a hole through the pipe.

Mr. S. J. Winslow. Was it what is called the old-fashioned make of cement pipe?

Mr. Haskell. The first 48 miles of it was what might be called the very best contract work. But perhaps our pipe stood as well as it does in any city. I should think it represented really a better class of work than is done in many cities.

Mr. S. J. Winslow. I know something about a pipe that is manufactured entirely of cement, with two jackets of sheet iron. I have had some experience with that, and I would like to know if you have had any acquaintance with it.

Mr. Haskell. We have had a piece of pipe we laid ourselves that probably came nearer such a pipe and that was laid with almost clear cement. Our old pipe was laid, I should judge, with certainly three parts of sand to one of cement, and wasn't properly mixed at that.

Mr. S. J. Winslow. That accounts for your trouble, probably.

Mr. Haskell. That is the trouble with it *largely*, but bursts mostly occur where the cement has been knocked off the iron. Where a sewer trench runs across a water main, the workmen are very apt to knock some of the cement off the pipe. Then again the excavation very often has a tendency to make a depression, the whole surface of the ground settles a little at that point, and that injures a cement pipe. And there are various causes that affect a cement lined pipe in a thickly settled city that do not apply to it in the outskirts, where the pipe is undisturbed. We have on our line that runs to the reservoir a 20-in. pipe, laid at the same time that this other pipe was laid and there has never been a burst on it or a leak on it that we have had to repair.

Mr. S. J. Winslow. Who laid that?

Mr. Haskell That was laid by the same party, but it extends through a territory where it has never been disturbed in any possible way.

Mr. S. J. Winslow. If I understand you, your judgment would be if that kind of pipe was laid as it should be, with proper care, it would be all right.

Mr. Haskell. I have had a good deal of experience with cement, and I have never felt any great confidence in mixing large quantities of it as we would have to in a line of cement pipe, that it would be possible to do the work and not have portions of the pipe which was covered with cement which would not be as strong as other portions of it I should not feel much confidence in it even with the greatest care.

Mr. S. J. Winslow. I know and fully understand that the standard pipe in this country, and I presume in all other countries, is of iron or it may be coming to be of steel. I will say that with an experience of eight years our cement pipe has proved highly satisfactory thus far. It is made of pure cement, and as far as our experience has gone we wouldn't want to change it for any pipe we have ever heard ot or seen.

Mr. Darling. I think after you have had an experience with that cement lined pipe as long as my friend has you may reverse your opinion. It was our misfortune at Pawtucket that in the original 24 miles of pipe that was laid we had a contractor who put in very short lead. And we have had, on the original 24 miles of pipe, a great many leaks as high sometimes as 200 leaks in a year, caused simply by the lead blowing out. Since that time I have superintended the laying of about 80 miles of pipe, and I don't know of 10 leaks on the 80 miles.

If you lay iron pipe and lay it properly, if you put in the lead as it ought to be, and give plenty of it, I never saw yet in my experience any trouble with it.

Now, at the price of iron pipe today, I should consider it foolish for any town, city or hamlet to undertake to put in what you call cement pipe. I believe in ten or fifteen years from now, he will get the same experience with this cement pipe that these gentlemen say they get at the present time; because I think and believe they tried to do, and did do, perhaps, full as good work in those days as they are doing today.

Mr. S. J. Winslow. I want to get at the facts. I know all about that old-fashioned cement pipe. I know all about how the iron pipe worked at Amesbury. If we are to have trouble, in 15 or 20 years I want to be prepared for it.

Mr. Darling. I believe it would be for your best interest to put iron pipe into the ground instead of putting in cement pipe.

Mr. Jones. I would like to ask one question of Mr. Haskell. (My experience has been altogether with iron pipe.) As he has had experience in both iron pipe and cement pipe, if there were two water works to be constructed of equal size which of the two he would prefer to take, one being cement pipe entire and the other one iron pipe entire. I would like to ask which he would select to take charge of, everything else being equal.

Mr. Haskell. I should take the iron pipe.

The President. We would like to hear from Mr. Walker.

Mr. Walker. I could talk all night about cement pipe, getting up nights and tumbling out of bed at all hours, if it would do the gentleman from Pittsfield any good, but it wouldn't, because his is a different kind of pipe. Mine is the old-fashioned pipe.

Mr. S. J. Winslow. It isn't like ours, is it?

Mr. Walker. No sir; mine will burst every 15 minutes. (Laughter.) About 18 years ago I was elected superintendent of the Manchester works. They then had about 28 miles of cement pipe, and I was told there wouldn't be much to do, that I would only have to look around once in a while and sign bills, and everything would take care of itself, so I thought I had better take the work. But I soon found out, and I say it today in all seriousness that, considering the responsibslity they take, superintendents of water works are the poorest paid men on earth. A manufacturing company which represents the same amount of money pays its superintendent three times as much as the men are paid who have charge of water works. The trouble is that everybody in the city thinks he can run the water works better than the superintendent. If you fail in anything you try to do, they will tell you they knew it would fail. And if you start something which turns out all right, up comes somebody who says, "Well, I should have thought you would have thought of that before." (Laughter.)

FIRE PROTECTION FOR MANUFACTURING ESTABLISHMENTS.

DISCUSSION.

Mr. Walker. I would like to inquire how large a pipe should be put into a mill or factory for sprinklers for fire protection? We will call the mill 200 feet long, 50 feet wide and three stories high; pressure on the mains 40 to 60 lbs. Is it customary to charge anything for putting in the pipe or for the use of the water so supplied? I ask these questions for I have tried to keep the size as small as possible because in case of a fire they break off sometimes. Now in the city of Manchester, say on Elm street, new blocks are being erected three to five stories high and not more than 50 feet front, we have on this street 60 lbs. pressure. If a 4-in. branch is put in to each place on both sides, they would be 25 feet apart.

We will suppose that we have a big fire on this street and four of these supply pipes break off and you could not get at the gates, it would take away the pressure to such an extent that serious damage would result to adjoining property. I think that owners of the property should pay for the expense of putting in the pipe and a rental besides. A city or private corporation should have to pay for increased fire protection whether for hydrants or automatic sprinklers.

Mr. Nevons. In Cambridge we put in any size they want and make them pay the whole bill. The largest we have put in so far is 8 inches.

Mr. Walker. Do they pay anything for the benefit they get from it?

Mr. Nevons. No. We seal it up, and in case of fire they have a right to break the seal, and they have to notify us and as soon as the fire is over we reseal the pipe.

Mr. Walker. How many pounds pressure have you?

Mr. Nevons. We have ordinarily about 30 pounds.

The President. Perhaps Mr. Freeman can give an opinion on this subject.

Mr. Freeman. I have had a very pleasant experience with a good many of you gentlemen in requesting pipes to be put in, and I think that all through the New England states we may say the custom is to put in pipes such as Mr. Nevons has described, and generally the mill pays the whole expense of putting it in. In places where the municipality owns the water works it is very rare indeed that any charge is made for the use of the water. It is considered that the factory is enough benefit to the town, that its protection is of enough interest to the citizens of the town, and that the taxes which they pay amount to enough to entitle them to receive the protection which such a pipe would give, and it is very rare that any charge in the way of a rental for fire service is made. Where the water company is a private corporation the practice varies. In some cases, in a great many cases, no charge is made except for water actually drawn. In other cases there is only a nominal rental, and in some cases there is quite a high rental charged. But the general prac-

tice, I think I may say, as far as my experience has extended, is that in a majority of cases the mill pays the bill for all expenditures of labor and material, but does not as a rule pay a rent.

Now, as to the size of the pipe which is permissable, that like everything else. depends a great deal on the surrounding conditions. In many cases a 12 inch pipe into a yard is not objectionable in any way, because there is ample room to provide a stop gate and arrange it so that it can be shut off in case of any breakage. There are other cases, of course, as in the streets of Boston, where anything larger than a 4 inch pipe could not be tolerated with safety. It is a matter which depends entirely upon the surrounding conditions. I think ordinarily by the exercise of a little skill, ingenuity, and foresight, in planning the entrance for the pipe, it can be placed at a point which is free enough from danger so that there is no extra hazard run by permitting the connection, that is, by locating the gate at a point where it might be reached under almost any circumstances.

Mr. Stacy. Mr. President, this question is one that we have had to consider in the city of Marlboro, where we have some of the largest shoe factories there are in New England. Our pressure there varies from 35 pounds to 105, and (I believe Mr. Freeman doesn't cover that district) they generally all want the same size pipe, no matter what the pressure is nor what the size of the pipe is with which they are to connect. Our practice has been to make sprinkler connections under the same conditions that we put in a service pipe, we carry it to the street line, and the rest of it is done at their expense, that is for the first pipe. For any additional pipe they have to pay the whole expense. The insurance companies by a reduction of rates have induced the factories to put in two services connecting with different sections of the main pipe with check valves so a break in one section between two gates would not deprive a shop of water for the fire sprinklers, and the manufacturers have always paid the entire expense for the second connection. As Mr. Freeman has suggested, the way we look on the question in the city of Marlboro is that the factories are the life of the city, and we should protect them to a certain extent. At the same time we consider that they should pay a certain amount of money towards the revenue of the city. There has been only one instance in which we have had to make any trouble, and that was where sprinklers were connected and the help had to go across the street to get water to drink; and we thought that possibly they were using some of the water from the sprinkler connection for their boilers, and we made them tap the pipe and put on a meter, and now they are using our water altogether. The water is free for fire protection, but no connection is allowed with the sprinkler connection except by a meter. The first connection is free to the street line on the same conditions that a service would be put in, and they pay the entire additional expense.

Mr. Fuller. I am a little interested in this matter. It has seemed to me, and the question came up with us in the town of Wellesley, where we have very little manufacturing, that on account of the large expenditure which had been made in order to give fire protection the mills should be willing to pay a small amount for that protection. And so for the few private hydrants we have in mill yards we have made a charge of $10, and also a

charge for sprinklers, I don't remember what, but not very much. It is true that towns ought to encourage manufacturing, but at the same time a great many of our water works have cost a great deal more money on account of being built to provide fire protection than they would if they were simply for domestic service, and I hardly see why the mill and factories in view of the reduction in insurance which they get, and the protection which they enjoy, should not be willing to pay something towards this increased cost of the works.

Mr. Richards. During the Lynn fire, as appears by Mr. Haskell's paper,* in spite of the greatest precautions, two 4 inch service pipes were broken by falling walls. They discharged for 20 hours or more, wasting at least one-half the water consumed, and greatly reducing the pressure. Yet the insurance companies are constantly demanding 4 inch and 6 inch service pipes to supply fire sprinklers and stand pipes. Would it not be well to consider a remedy for this?

In the narrow streets often found in New England cities, placing gates at the opposite curb would but slightly decrease the liability of being covered by falling walls, and it would seem that the "Indicator Post Valve," with stem above the surface, is more likely to be damaged than the underground gate.

It would appear that the insurance companies are willing to jeopardize the surrounding property to protect their particular risk.

Mr. Freeman. As to the case quoted from Mr. Haskell's paper where two 4-in. service pipes were broken by falling walls, a kind of accident for which Mr. Richards very properly suggests that a remedy should be looked for, I would say that had these pipes been guarded by shut-off valves properly located in the manner suggested in my paper on this subject† this loss of water need not have happened.

We have by no means obtained our ideal in the older mill yards, but we are steadily progressing toward it.

For several years past special care has been taken in our factory yards to provide an easily accessible and very conspicuous "outside shut off" for every large pipe leading inside the mill.

Several hundred of the "Indicator Valve Posts" illustrated in my paper, have been put in for this purpose in factory yards during the past two years and in a few instances it has happened that when I have urged a water works superintendent to put in something of this kind at the curb stone line or at the fence line, or even at the curb stone line across the street, (running over and placing gate on opposite side of street and coming back with a return bend in order to get the said indicator gate post beyond the reach of falling walls,) he has sometimes told me that he guessed the old style under-ground gate with all the possibilities of the gate box being filled by gravel and ice, or the cover being frozen down or hidden, or where it could not be operated without half an hour's vigorous work, "would do."

The remedy for preventing these wastes of water is plain, all that is needed is for more superintendents to vigorously apply the remedy.

*Vol. VII. p. 47.
†Vol. VII, p. 57.

As to the "Indicator Gate Post" being more susceptible to damage by a falling wall than an underground gate I would say that the gate itself is precisely the same in either case. The "Indicator Post" is merely a long stem with a tell-tale attached and an outer iron case to protect the whole. This stem is connected to the regular gate stem in such a loose or flexible way that no injurious blow would probably ever be transmitted to the main gate by its means.

In reply to Mr. Richards' suggestion that in urging these large pipes for sprinkler supplies off the city mains the underwriters—in so protecting one risk jeopardize its neighbors—it is to be said that experience, as well as reason, proves that whatever is done to make one building safe, adds also to the safety of its neighbors.

In the great Boston fire of a few days ago, the sprinklers in the Brown & Durrell building made all the surrounding property safer, and indeed, it is claimed by excellent judges, that had it not been for the retarding effect of these sprinklers the fire would have cut a clean swath through to Washington street.

Furthermore, I am informed on most excellent authority that Brown & Durrell had, a few months ago, begged their neighbors, Partridge & Co., to install sprinklers as they had done, that the whole neighborhood might be safer. Had they heeded this, the Brown & Durrell and Partridge & Co's. buildings would undoubtedly be standing today.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

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This Association, as a Body, is not responsible for the statements or opinions of any of its members.

ADJOURNED MEETING.

PARKER HOUSE, BOSTON, MASS., FEBRUARY 8TH, 1893.

The following members and guests were present :

MEMBERS.

Everett L. Abbott, Civil Engineer, New York City; Charles F. Allen, Treasurer, Hyde Park, Mass.; Charles H. Baldwin, Boston, Mass.; George E. Batchelder, Registrar, Worcester, Mass.; Joseph E. Beals, Supt., Middleboro, Mass.; Nathan B. Bickford, Supt. Water Works, O. C. R. R., Boston, Mass.; William R. Billings, Taunton, Mass.; George Bowers, City Engineer, Lowell, Mass.; Dexter Brackett, Asst. Engineer, City Engineer's Office, Boston, Mass.; Arthur W. F. Brown, Registrar, Fitchburg, Mass.; Ernest H. Brownell, Brown University, Providence, R. I.; Fred. I. Chaffee, Chairman Executive Board, Providence, R. I.; George F. Chace, Supt., Taunton, Mass.; Charles E. Chandler, City Engineer, Norwich, Conn.; Freeman C. Coffin, Boston, Mass.; R. C. P. Coggeshall, Supt., New Bedford, Mass.; H. W. Conant, Supt., Gardner, Mass.; F. W. Clark, Clerk Chestnut Hill Reservoir, Boston Water Works, Brighton, Mass.; Henry A. Cook, Supt., Salem, Mass.; George K. Crandall, Asst. Engineer, New London Conn.; Lucas Cushing, Asst. Supt., Boston, Mass.; Edwin Darling, Supt., Pawtucket, R. I.; William G. Curtis, Asst. Biologist, Boston Water Works, Brighton, Mass.; Nathaniel Dennett, Supt., Somerville, Mass.; Elmer E. Farnham, Supt., Sharon, Mass.; B. R. Felton, City Engineer, Marlboro, Mass.; Z. R. Forbes, Asst. Supt., Brookline, Mass.; John R. Freeman, Civil Engineer, Boston, Mass.; Frank L. Fuller, Civil Engineer, Boston, Mass.; L. L. Gerry, City Engineer, Dover, N. H.; Albert S. Glover, Boston, Mass.; W. J. Goldthwait, Marblehead, Mass.;

J. A. Gould, Jr., Asst. Engineer, City Engineer's Office, Boston, Mass.; Frederick W. Gow, Supt., Medford, Mass.; Sherman E. Grannis, Supt., New Haven, Conn.; John L. Harrington, Cambridge, Mass.; John Harris, Commissioner, Waltham, Mass.; John C. Haskell, Supt., Lynn, Mass.; L. M. Hastings, City Engineer, Cambridge, Mass.; Louis E. Hawes, Civil Engineer, Boston, Mass.; Allen Hazen, Chemist, Lawrence, Mass.; Horace G. Holden, Supt., Nashua, N. H.; Willard Kent, Civil Engineer, Woonsocket, R. I.; Patrick Kieran, Supt., Fall River, Mass.; George A. Kimball, Civil Engineer, Boston, Mass.; Thomas C. Lovell, Supt., Fitchburg, Mass ; Josiah S. Maxcy, Treasurer, Gardner, Maine; William McNally, Registrar, Marlboro, Mass.; Edward C. Nichols, Commissioner, Reading, Mass.; John H. Perkins, Supt., Watertown, Mass.; Edward H. Phipps, Supt., West Haven Water Co., New Haven, Conn.; Charles E. Pierce, Supt., East Providence, R. I.; Prof. Dwight Porter, Mass. Inst. Technology, Boston, Mass.; Waldo E. Rawson, Supt., Uxbridge, Mass.; Walter H. Richards, Supt., New London, Conn.; George J. Ries, Supt., Weymouth Centre, Mass.; A. H. Salisbury, Supt., Lawrence, Mass.; Arthur F. Salmon, member Water Board, Lowell, Mass.; William T. Sedgwick, Prof. Biology, Mass. Inst. Technology, Boston, Mass.; George A. Stacy, Supt., Marlboro, Mass.; Eugene S. Sullivan, Supt., Mystic Division Charlestown, Boston, Mass.; Edwin A. Taylor, Civil Engineer, Boston, Mass.; M. M. Tidd, Civil Engineer, Boston, Mass.; D. N. Tower, Supt., Cohasset, Mass.; C. H. Truesdell, Civil Engineer, North Grosvenordale, Conn.; W. H. Vaughn, Supt., Wellesley Hills, Mass.; Charles K. Walker, Supt., Manchester, N. H.; Robert J. Thomas, Supt., Lowell, Mass.; W. P. Whittemore, Supt., North Attleboro, Mass.; Frederick I. Winslow, Boston, Mass.; George E. Winslow, Supt., Waltham, Mass.; S. J. Winslow, Supt., Pittsfield, N. H.; E. T. Wiswall, Commissioner, West Newton, Mass.; E. R. Jones, Boston, Mass.; F. W. Shepperd, "Fire and Water," New York city; James M. Betton, Agt. H. R. Worthington, Boston, Mass.; A. H. Broderick, Chadwick Lead Works, Boston, Mass.; Edward L. Ross, Chapman Valve Mfg. Co., Indian Orchard, Mass.; F. H. Hayes, Dean Steam Pump Co., Holyoke, Mass.; H. N. Libbey and G. A. Taylor, Gilchrist & Taylor, Boston, Mass.; J. A. Tilden, Hersey Mfg. Co., South Boston, Mass.; Henry F. Jencks, Pawtucket, R. I.; F. E. Stevens and S. B. Adams, Peet Valve Co., Boston, Mass.; H. L. Bond, Perrin, Seamans & Co., Boston, Mass.; I. W. Dodge, Standard Thermometer Co., Boston, Mass.; E. J. Snow, Thomson Meter Co., Brooklyn, N. Y.; J. P. K. Otis and G. H. Carr, Union Water Meter Co., Worcester, Mass.; B. F. Polsey, and J. H. Eustis, Walworth Mfg. Co., Boston, Mass.; H. A. Gorham, secretary the George Woodman Co., Boston, Mass.; H. G. H. Tare, H. R. Worthington, New York city.

GUESTS.

W. F. Allen, Boston, Mass.; A. W. Barns, Fitchburg, Mass.; R. D. Chase, Boston, Mass.; James Daley, Uxbridge, Mass.; John Dexter, North Grosvenordale, Conn.; A. J. Fabens, Salem, Mass.; A. Prescott Folwell, Newark, N. J.; C. R. Felton, Brockton, Mass.; Charles Firth, W. K. Harrington, Newport, R. I.; D. A. Hartwood, Fitchburg, Mass.; J. A. Higgins, Providence, R. I.; J. H. Howland, Boston, Mass.; E. W. Kent, Woonsocket, R. I.; J. W.

Milne, Fall River, Mass.; L. S. Pope, Boston, Mass.; H. P. Quick, John F. Simmons, Hanover, Mass.; George R. Stetson, S. H. Taylor, New Bedford, Mass.; Richard J. Tingley, Pawtucket, R. I.; G. C. Whipple, Brighton, Mass.; George E. Williams, Boston, Mass.; W. T. Wyman, Boston, Mass.

After lunch was served, President Chace called the meeting to order. The Secretary read the following applications for membership:

RESIDENT ACTIVE.

John J. Cavanagh, Water Commissioner, Quincy, Mass.
Herbert T. Whitman, Water Commissioner, Quincy, Mass.
John Macnair, member Water Board, Lynn, Mass.
D. A. Sutherland, member Water Board, Lynn, Mass.
George C. Whipple, Biologist, Boston Water Works, Chelsea, Mass.
Leonard P. Kinnicutt, Worcester Polytechnic Institute, Worcester, Mass.
James H. Higgins, Supt. Meter Dept., Providence, R. I.
Charles H. Bartlett, Civil Engineer, Manchester. N. H.
R. H. Tingley, Civil Engineer, Pawtucket, R. I.

NON-RESIDENT ACTIVE.

John A. Berkey, President Little Falls Water Power Co., St. Paul, Minn.

On motion of Mr. Brackett the Secretary was directed to cast the ballot of the Association for the gentlemen named above, which he did, and they were declared elected members of the Association.

The attention of the members was then invited to a paper by Mr. Freeman C. Coffin, Hydraulic Engineer, Boston, on "Standpipes—their Construction and Design."

At the conclusion of Mr. Coffin's paper the President introduced Mr. A. Prescott Folwell, of Orange, N. J., who read a paper descriptive of a somewhat novel standpipe erected at Atlantic Highlands, N. J.

Mr. John C. Haskell, superintendent, Lynn, Mass., gave an interesting account of his experience with cement pipe. The discussion following was participated in by Mr. Jones of Boston, Mr. Winslow, of Pittsfield, N. H., and Mr. Darling of Pawtucket.

Mr. Walker of Manchester, N. H., then gave a short experience talk on "Fire Protection to Manufacturers."

On motion of the Secretary the thanks of the Association were tendered to Mr. F. S. Pierson, Chief Engineer of the West End Railway Co., for courtesies shown the Association to-day.

[Adjourned.]

During the forenoon many members made an excursion to the power station of the West End Railway Co., being shown about the works by Mr. F. S. Pierson, Chief Engineer of the Company.

QUARTERLY MEETING.

Parker House, Boston, Mass., March 8th, 1893.

Previous to the formal meeting a very interesting exhibition of microscopic slides and photographs of different algæ and infusoria was made by Desmond FitzGerald, F. F. Forbes and Geo. F. Chace.

The following members and guests were in attendance:

MEMBERS.

Everett L. Abbott, Civil Engineer, New York City; Chas. F. Allen, Treasurer, Hyde Park, Mass.; Frank A. Andrews, Asst. Supt, Nashua, N. H.; Chas. H. Baldwin, Boston, Mass.; Albert P. Barrett, Registrar, Woburn, Mass.; Geo. E. Batchelder, Registrar, Worcester, Mass.; Joseph E. Beals, Supt. Middleboro, Mass.; Nathan B. Bickford, Supt. W. W. O. C. R. R., Boston, Mass.; Geo. Bowers, City Engineer, Lowell, Mass.; Dexter Brackett, Asst. Engineer, City Engineers Office, Boston, Mass.; George F. Chace, Supt., Taunton, Mass.; Chas. E. Chandler, City Engineer, Norwich, Conn.; Freeman C. Coffin, Civil Engineer, Boston, Mass.; R. C. P. Coggeshall, Supt., New Bedford, Mass.; Frederick W. Clark, Clerk, Chestnut Hill Reservoir, Brighton, Mass.; Byron I. Cook, Supt., Woonsocket, R. I.; Geo. K. Crandall, Asst. Engineer, New London, Conn.; P. F. Cully, Supt. Woburn, Mass.; Lucas Cushing, Asst. Supt., Boston, Mass.; Prof. Thos. M. Drown, Mass. Inst. Tech., Boston, Mass.; Horace L. Eaton, City Engineer, Somerville, Mass.; B. R. Felton, City Engineer, Marlboro, Mass.; F. F. Forbes, Supt., Brookline, Mass.; Desmond FitzGerald, Supt. Western Division Boston Water Works, Brookline, Mass.; Frank L. Fuller, Civil Engineer, Boston, Mass.; John R. Freeman, Hydraulic Engineer, Boston, Mass.; W. J. Goldthwait, Marblehead, Mass.; Richard A. Hale, Hydraulic Engineer, Lawrence, Mass.; Geo. W. Harrington, Supt., Wakefield, Mass.; John L. Harrington, Cambridge, Mass.; John Harris, Commissioner, Waltham, Mass.; L. M. Hastings, City Engineer, Cambridge, Mass.; Clemens Herschel, Hydraulic Engineer, New York City; Horace G. Holden, Supt., Nashua, N. H.; James H. Higgins, Supt. Meter Dept., Providence, R. I.; Horatio N. Hyde, Supt., Newtonville, Mass.; Geo. A. Kimball, Civil Engineer, Boston, Mass.; E. W. Kent, Civil Engineer, Woonsocket, R. I.; Eugene P. LeBaron, Chairman, Middleboro, Mass.; Wm. McNally, Registrar, Marlboro, Mass.; Albert F. Noyes, City Engineer, West Newton, Mass.; Edward H. Phipps, Supt., New Haven, Conn.; Walter H. Richards, Supt., New London, Conn.; Geo. J. Ries, Supt., Weymouth Centre, Mass.; Henry W. Rogers, Supt., Haverhill, Mass.; Edward W. Shedd, Civil Engineer, Worcester, Mass.; Geo. A. Stacy, Supt., Marlborough, Mass.; Edwin A. Taylor, Civil Engineer, Boston, Mass.; Jos. G. Tenny, Supt., Leominster, Mass.; Robert J. Thomas, Supt., Lowell, Mass.; M. M. Tidd, Hydraulic Engineer, Boston, Mass.; D. N. Tower, Supt., Cohasset, Mass.; W. H. Vaughn, Supt., Wellesley Hills, Mass.; Chas. K. Walker, Supt., Manchester, N. H.; Geo. C. Whipple, Biologist, Boston Water Works, Brighton, Mass.; Horace B. Winship, Civil Engineer, Norwich, Conn.; Geo. E. Winslow, Supt., Waltham, Mass.; E. T. Wiswall, Commissioner, West Newton, Mass.; E. Worthington, Jr., Civil En-

gineer, Boston, Mass.; Richard R. Yates, Supt., Northboro, Mass.; James M. Betton, H. R. Worthington, Boston, Mass.; A. H. Broderick, Chadwick Lead Works, Boston, Mass,; F. H. Hayes, Dean Steam Pump Co., Holyoke, Mass.; Chas. H. Eglee, Contractor, Flushing, N. Y.; Geo. A. Taylor, Gilchrist & Taylor, Boston, Mass.; Henry F. Jenks, Pawtucket, R. I.; S. B. Adams and F. E. Stevens, Peet Valve Co., Boston, Mass.; H. L. Bond, Perrin, Seamans & Co., Boston, Mass.; H. H. Kinsey, Renssealer Mfg. Co., Troy, N. Y.; H. C. Folger, Thomson Meter Co., Brooklyn, N. Y.; W. H. Moulton, Supt. Union Water Meter Co., Worcester, Mass.; Geo. B. Wood, R. D. Wood & Co., Philadelphia, Penn.; H. A. Gorham, The Geo. Woodman Co., Boston, Mass.

GUESTS.

Richard B. Allen, Lowell, Mass.; Hon. J. C. Brock, New Bedford, Mass.; J. W. Cassidy, Lowell, Mass.; D. W. Darling, Worcester, Mass.; Henry T. Fantom, Rockland, Mass.; Geo. W. Fuller, Lawrence, Mass.; Herman Gregg, Waltham, Mass.: Chas. T. Main, Civil Engineer, Boston, Mass.; W. F. Murphy, Brighton, Mass.; A. B. Rice, Boston, Mass.; Braddish J. Smith, New York City; F. L. Taylor, Brookline, Mass.; S. H. Taylor, New Bedford, Mass.

The Secretary presented the names of the following named candidates for active membership:

RESIDENT ACTIVE.

William E. Foss, Asst. Engineer Boston Water Works, 10 Fairview street, Dorchester, Mass.

George W. Fuller, Biologist, Lawrence Experimental station, Lawrence, Mass.

Joseph K. Nye, Fairhaven, Mass.

Caleb M. Saville, Civil Engineer, 44 Clarenden street, Malden, Mass.

Henry T. Fantom, Rockland, Mass.

NON-RESIDENT ACTIVE.

Watson L. Bishop, Superintendent Water Works, Dartmouth, Nova Scotia.

On motion of Mr. Brackett the Secretary was directed to cast the ballot of the association for the above named gentlemen, which he did, and they were declared elected.

On motion of Mr. Holden the president was instructed to appoint a committee of three to nominate officers for the ensuing term and to report at the June meeting. The president appointed Messrs. Horace G. Holden, Frank E. Hall and Charles K. Walker as the committee.

Mayor Brock of New Bedford was then presented by President Chace, and he briefly addressed the association.

The regular programme for the afternoon was then taken up, and Mr. L. M. Hastings, City Engineer, Cambridge, Mass., read a paper entitled "Description of a Method of Estimating the Loss of Water Power in a Stream by Taking Water therefrom for a City Supply." The paper was discussed by Mr. Herschel, Mr. Freeman, Mr. Kimball, Mr. Hale and Mr. Charles T. Main.

Mr. George A. Stacy, of Marlboro, and Mr. F. L. Fuller, of Boston, presented brief experience papers, and after the president had expressed his thanks to the members for the interest they had taken in the winter meetings and expressed the hope that he would see a full attendance at the annual meeting in Worcester, the association adjourned.

A METHOD OF ESTIMATING THE LOSS OF WATER POWER IN A STREAM BY TAKING WATER THEREFROM FOR A CITY SUPPLY.

BY

L. M. Hastings, City Engineer, Cambridge, Mass.

Perhaps one of the most uncertain and vexatious questions which comes to a community or corporation proposing to take water from a source which is, or may be, used for private purposes, is that of the damages which may be obtained by the owners to be affected by such taking. The cost of erecting the necessary works, piping, reservoirs, etc., can be estimated with tolerable accuracy, and the money expended for them has a tangible equivalent whose utility is apparent, but the amount of money to be obtained by the interested parties in the source from which the supply is taken is never easily estimated in advance, and seldom satisfactorily adjusted after the taking has been made.

Large sums are often expended in settlement of such claims for which little can be shown the inquiring taxpayer or stockholder.

The settlement of such claims has proved a very fruitful source of cases heard by commissioners or in the courts, for I think it is quite generally the experience that it is seldom that a settlement can be made with owners except by reference to such tribunals.

While it is impossible to ascertain precisely the number of such cases heard during the last 15 years in the state of Massachusetts for instance, it is certain that the number must be very large, and will be likely to increase as the introduction of public supplies become more general in the smaller communities of the country, and as the capacity of the old supplies are exceeded by the demands upon them and are sought to be reinforced with additional supplies.

In the preparation of these cases for hearing some very interesting problems in hydraulic and water supply engineering are often raised.

Engineers of high standing, engaged by the contesting sides are pitted against each other and sometimes the most surprising differences in results are reached

While in some cases there may be local conditions and peculiarities which must be considered in estimating the value of the supply, yet there is in all the cases certain facts and principles which must be ascertained and applied in obtaining that criterion of value by which most of the sources of water supply are measured, viz: the *capacity of the stream for work* as measured in *average daily horse power.*

The amount of water and its value as used in manufacturing—other than as power—is a separate question and will not be considered at this time.

As an interesting case illustrating the methods which may be followed in estimating the power of a stream and the loss by taking from it, I propose to give as briefly as I can, some of the points in a suit brought by the owners of certain mills and water power on Charles river in Waltham and Wa-

tertown against the city of Cambridge, for the loss of water power caused by taking the water of Stony Brook for an additional water supply.

Since 1856 Fresh Pond has been a source of supply for the city. This supply proving inadequate, after various attempts to secure an additional supply, in 1885 the right was obtained from the legislature of the state to divert and use the water of Stony Brook and its tributaries in the city of Waltham and the towns of Weston and Lincoln for an additional supply supplementing that to be obtained from Fresh Pond.

The works were completed and the water let on from the Stony Brook reservoir in the fall of 1887.

After the settlement of various suits for loss of water power on Stony Brook itself, the owners of the four powers on Charles river, below its junction with Stony Brook, brought suit as I have said for compensation for loss of power in the river by the diversion of the water of Stony Brook its tributary.

The two upper dams at Waltham were owned by the Boston Manufacturing Company, the third dam, at Watertown, was owned by the Ætna mills, and the lower dam at Watertown Centre, was controlled by three parties jointly, the Watertown grist mill, Walker, Pratt & Co., foundry, and Hollingsworth & Whitney, paper manufacturers.

The claim made by each of the parties was the same in principle, although the drainage area was slightly increased at each successive dam, no notice was paid to the fact, and their claim was made proportionally to the head or fall at each dam.

Their statement of the case was very simple. It had been agreed by both sides that the yield of the 23 square miles of water shed of Stony Brook would be in an average year about 22⅓ million gallons daily.

Now this flow of 22⅓ million gallons daily, passed over the dam at Waltham of the Boston Manufacturing company with a fall of 12.10 feet, and 80 per cent. efficiency at the wheels would produce 90.6 horse power. This at the valuation placed upon a horse power by the agent of the company of $800 per horse power, gave a loss of $72,480. At the same company's lower or "Bleachery" dam, having a fall of 4.00 feet, a loss of 30 horse power on $24,000 was claimed.

At the Ætna mills dam, with a fall of 4.80 feet a loss of 36.0 horse power or $28,800 was claimed. At the Watertown dam having a fall of about 5.80 feet a loss of 43.40 horse power or $34,720 was claimed. making a total loss of 200 horse power valued by the owners at $160,000.

The city's defense against this claim was that but little and practically no loss of horse power was occasioned by the taking of such water of Stony Brook as the city could use, for the reason that in the seasons of the year when large quantities of water was flowing in Stony Brook, vast quantities of water were being wasted over the dams on Charles river owing to lack of pondage sufficient to retain the water until it could be used. and that when the seasons of lower flow came on, when the flow of the brook could be *used* and *not wasted*, the flow itself became so small as to be of little value.

Also it was sought to be shown that water power itself has but very little value at the present time any way.

This latter, an exceedingly interesting question, I shall not touch upon today, but shall try and explain how the former was attempted to be shown to the commission.

The drainage area is an important element in determining the power to be derived from any stream.

Charles river has its source in the town of Milford, Mass , from there flowing by a very circuitous route in a general north-easterly direction to the sea. On its way as it passes the town of Dedham it is tapped by a brook, partly natural and partly artificial, formerly called "Mill Creek" but now called Mother Brook, which flows from the Charles river into the Neponset river. This connection between this old "Mill Creek" and Charles river is by a ditch or canal through the meadows dug in 1639 at "common charges" as the quaint old records say. The digging of the ditch and consequent diversion of water from Charles river caused much litigation amongst the mill owners which went on until 1831, nearly 200 years after, when an agreement was signed by the mill owners on the two streams by which one-third of the water in Charles river at this point was to be diverted into Mother Brook and the remaining two-thirds was to continue to flow in the river, so that the drainage area of Charles river at any point below its junction with Mother Brook must be reduced by one-third the area above, or 66.64 square miles. The entire drainage area of Charles river above the dam of the Boston Manufacturing company is 251.42 square miles, deducting the 66.64 square miles above referred to, gives 184.78 square miles available drainage area of the river at this point.

No better data concerning the yield to be expected from a water shed in this vicinity can be obtained than the records given in the reports of the Boston Water Board of the observed yield of the basins of that system. These records were used in the computations which follow.

Another important element of water power is *storage capacity* or more properly "*pondage*." Using the word storage to mean capacity to store or carry over a quantity of water from a wet season to a dry one and "pondage" the capacity to hold the night flow for use in the working hours of the following day. This last is the most usual method.

The amount of pondage exerts a very marked influence on the development of water power from the natural flow of a stream.

Thus in the case of the Boston Manufacturing company if they had no pond and took simply the natural flow of the stream as it came, but 289 horse power would be obtained from the river. With the pond which they have 503 horse power can be obtained, while with a pond large enough to retain the entire night and Sunday flow, about 809 horse power could be obtained. The amount of pondage depends not only on the *size* of the pond but on the elevation to which the water can be raised or lowered It is desirable, of course, to keep the water level as high as possible. If the draught, or low water line is not fixed by any riparian rights, then the *economical limit* must be determined by computation, for there will always be a point below which the gain in volume of water to be used will be offset by the resulting loss of head, as the pond is lowered.

The pond of the Boston Manufacturing company is the surface of the river extending from their dam to near the dam at Newton Lower Falls, a distance of nearly 5 miles, giving a surface area of about 10,750,000 square feet. The water can be drawn down at the dam about 2 feet below the flood line or level giving a pondage equal to 22,400 cubic feet per min. to be used in addition to the natural flow of the stream. This 22,400 cubic feet to be held back and stored in the pond during the 14 hours in which the mills are not running, and used in the 10 hours of the day when the mills *are* running.

Having the other elements determined, the power will vary directly as the head or fall of the stream. This can only be determined by careful measurements on the ground.

In order to present as clearly as possible just the power of the river and the effect on that power by abstracting the water of Stony Brook from it, the following exhibit, slightly condensed from the original, was made to the commissioners.

EXHIBIT NO. 1.

Showing Horse Power of Charles River at the Dam of the Boston Manufacturing Company in Waltham.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
	Rainfall Collectable.	Amount collected and flowing off per month. (Area 184.78 square miles)	Amount flowing off per minute.	Amount of flow available for power in river.	Amount of flow not available for power.	Amt. of pondage. (To be added to amt. in col. IV.)	Gross amount available for power.	Power with effective head of 11. feet. 75 per cent. efficiency at the wheels.
	Ins.	Cubic feet.	Cubic feet per minute					Horse Power
January...	2.005	860,700,000	19,281	18,000	1,281	22,400	40,400	630.24
February .	3.206	1,376,260,000	33,831	26,000	7,831	22,400	48,400	755 04
March ..	4.997	2,145,100,000	48,053	26.000	22,053	22,400	48,400	755.04
April	3.609	1,549,260,000	35,862	26,000	9,862	22,400	48,400	755.04
May	1.987	852,970,000	19,107	18,000	1,107	22,400	40,400	630.24
June.	0.864	370,894,500	8,585	8,000	585	14,154	22,154	345 64
July	0.335	143,807,000	3,221	3,000	221	5,266	8,266	128.90
August....	0.549	235,670,000	5,279	5,000	279	8,777	13,777	214.90
September	0.457	196,180,000	4,541	4,500	41	7,961	12,461	194.40
October...	1.053	452,030,000	10,126	9,500	626	16,677	26,177	408.36
November	1.617	694,130.000	16,068	15,500	568	22,400	37,900	591.24
December.	1.940	832,790.000	18,656	18,000	656	22.400	40.400	630.24

12)6,039.28

Average daily horse power for the year = 503.27

EXHIBIT NO. 2.

Showing Horse Power of Charles River at the Dam of the Boston Manufacturing Co., in Waltham after Diverting all the Water of Stony Brook.

	I.	II.	III.	IV.	V.	VI.
	Rainfall collectable.	Amount flowing off area 161.78 square miles.	Amount of flow in river available for power.	Amount of pondage to be added to column III.	Gross amount available for power.	Power with effective head of 11 ft. 75 per cent efficiency at the wheels.
	Inches.	Cubic feet per minute.				Horse Power.
January	2.005	16,871	15,750	22,400	38,150	595.14
February	3.206	29,600	22,750	22,400	45,150	704.34
March	4.997	42,046	22,750	22,400	45,150	704 34
April	3.609	31,379	22,750	22,400	45,150	704.34
May	1.987	16,718	15,750	22,400	38,150	595.14
June	0.864	7,512	7,000	12,385	19,385	302.41
July	0.335	2,818	2,275	4,958	7,233	112.83
August	0.549	4,617	4,375	7,680	12,055	188.06
September	0.457	3,973	3,938	6,966	10,904	170.10
October	1.053	8,860	8,313	14,592	22,905	357.32
November	1.617	14,060	13,563	19,600	33,163	517.34
December	1.940	16,324	15,750	22,400	38,150	595.14

12)5,546.50

Average daily horse power for the year = 462.20

Horse Power of Charles River, including Stony Brook, (Exhibit No. 1.) = 503.27 H. P.
Horse Power of Charles River, excluding Stony Brook, (Exhibit No. 2.) = 462.20 H. P.

Net loss of power as shown above = 41.07 H. P.

EXHIBIT NO. 3.

Showing Horse Power of Charles River allowed by the City of Cambride as lost to the Boston Manufacturing Co. by taking the water of Stony Brook.

		IV.	V.	VI.	VII.	VIII	IX.	X.
		Amount of flow in River available for power.	Amount of flow not available for power.	Amt. of flow wasted over dam as shown by Boston Mfg. Co.'s records.	Flow of Stony Brook 23 square miles.	Estimated loss for power in natural flow of river.	Estimated loss (Col VIII) developed by pondage.	Net H. P. on fall of 11 ft. 75 per cent efficiency at at the wheels.
		Cubic feet per minute.						Horse Power
January.	Col's I., II., III. same as shown in Exhibit No. 1.	18,000	1,281	5,215	2,180	...	.....	.....
February		26,000	7,831	10,800	4,092	...	....	.....
March		26,000	22,053	13,830	5,005	...	.....	.....
April		26.000	9,862	11,570	3,889	...	...	.....
May		18,000	1,107	6,715	2,260	...	....	....
June		8,000	585	1,907	1,065	533	1,475	23.01
July		3,000	221	68	549	549	1,572	24.54
August		5,000	279	380	698	698	1,923	30.00
September.		4,500	41	891	652	652	1,805	28.15
October		9,500	626	1,069	959	959	2,642	41.22
November		15,500	568	2,294	1,700	850	2,449	38.21
December		18,000	656	4,353	1.989	..	....	.....
								12)185.13

Allowed loss of horse power in Charles River by taking Stony Brook = 15.43

In Exhibit 1, *Column* I., shows the amount of water which may be expected to flow off from the drainage area in an average year and is given in inches of rainfall. This is based on the observed quantity flowing off from the adjacent water shed of the Sudbury river and is the average of many years observations.

Column II., is this amount of rainfall put into cubic feet per month from the area of water shed or 184.78 *square miles.*

Column III., is this amount reduced to cubic feet per minute.

Column IV., is based on the observed fact that in all streams it has been found impossible to utilize all the flow of the stream for power, but during storms and freshets a certain quantity will invariably be wasted.

This quantity wasted has never been accurately determined but is variously estimated at from 16 to 30 per cent. of the total yearly flow, mostly occurring in the three wet months of February, March and April.

It has also been found that it is impossible to design the wheel plant to take all the water as it comes – some water must be wasted or the wheels will work with a lower efficiency at times. In this column about 20 per cent. has been considered as wasted, which waste is shown in *Column* V.

Column VI. shows the amount of water in addition to the natural flow of the river shown in column IV., which may be held in the pond above the dam and used in the 10 working hours.

As will be noticed for the 5 months—June to November—all the flow of the river can be retained, and for the remaining 7, only the capacity of the pond, sufficient to give 22,400 cubic feet per min. can be held, the excess over this amount being wasted.

The total amount of water available for power shown in column VII. is reduced to horse power in column VIII. with a head of 11 feet—for while the whole head or fall is 12.10 feet, a certain amount of head is always lost in getting the water on and off the wheels, and also by the drawing down of the pond. Seventy-five per cent. of the gross power has been taken as the efficiency of first-class wheels.

The resulting daily horse power is 503.27 as shown.

To find the theoretical loss of power in the river by taking from it the water of Stony Brook the same method is followed, with a smaller water shed or drainage area, as shown in Exhibit No. 2. Instead of a drainage area of 184.78 square miles, we now substract the 23 square miles of water shed in Stony Brook, giving an area of 161.78 square miles.

The resulting power of the river is 462.20 horse powers. As the power of the river before taking out Stony Brook was 503.27, the difference, or 41.07 horse power would represent the calculated loss to the company. This would be *the most* that they could fairly claim and in a majority of cases if the entire flow of the stream was taken, would represent the loss of power in the river by such taking.

But as it would be a practical impossibility for *all* the water of the brook to be diverted, another exhibit was prepared which is shown here as Exhibit No. 3 and shows a somewhat different study of this case with additional data.

In this exhibit, columns I. to V. are identical with those shown in Exhibit No. 1.

For many years the Boston Manufacturing company have kept a record of the amount of water (depth in inches) flowing over their dam, observations being taken four times daily. Access to these records were kindly given me by the company, and the average amount wasted over their dam for a period of 10 years is shown in column VI.

The amounts estimated as wasted in column V. and that shown in column VI., while not precisely agreeing, yet show a strong general similarity in range, and were used as a study and comparison together, and with column VII. which gives the flow of the Stony Brook water shed of 23 square miles.

From a comparison of these three columns, the conclusion was drawn that during the months of January, February, March, April, May and December more water was wasted at the dam than the entire flow of Stony Brook.

This will be corroborated by a study of column IV., Exhibit 2, where it will be noted that the pond has not capacity to hold during the months above named, the night flow, even after the substraction of Stony Brook.

During the months of June and November it was allowed that one-half the flow of Stony Brook would be lost, and the entire flow during July, August, September and October as shown in column VII. This volume, developed by pondage is shown in column IX. and reduced to horse power in column X.

This reduced to a daily average for the year gives 15.43 horse power as the allowed loss at this dam.

During these months therefore it was claimed that no loss to the company would result by taking the water of Stony Brook, this taking simply reducing the amount of waste. Indeed it might be claimed that this would be a benefit rather than an injury by lowering the back water below the dam.

Associated with me on this case were Mr. N. Henry Crafts and Mr. Richard A. Hale. Both reached substantially the same results by somewhat different methods. Mr. Crafts assumed that as the mills claimed, and were fitted up for but 500 horse power there was no loss until the power fell below that amount. His estimate of loss was 14.71 horse power. Mr. Hale took the water required to give full power on the wheels and when there was not enough water to give full power computed the difference with and without Stony Brook, reaching substantially the same result.

On the basis of 15.43 horse power being lost at the upper dam the total loss at the four dams would be 34.33 horse power instead of 200 horse power as claimed.

Instead of a damage of $160,000 as claimed, the commissioners awarded as the total damage at the four dams, the lump sum of $15,000, which award was accepted by both parties.

DISCUSSION.

Mr. Herschel. I desire to call the attention of the gentlemen present to one feature of this matter of the taking of the flow of brooks and rivers for the domestic supply of cities and towns ; and of the consequent questions of damages to mill owners for the so-called diversion of water. This whole subject cannot be separated from the legal aspects of the case, and a great deal of confusion is often caused in these hearings by lack of harmony between the labors of the engineers and of the wants and silent desires of the referees.

Nor need we be repelled by a seeming abstruseness of the points I am about to mention, merely because they are a part of the law. No subject, as has been said, is so abstruse but that an able presentation of it will make it plain. By dint of frequent association with lawyers in these cases, and hearing their able presentation of them, and from the decisions in such cases, I have gathered one simple proposition, which must be the goal in all valid computations and arguments in such estimations of damages

The closer it is kept in view, the less waste time will be included in the presentation of a case, and referring particularly to the labors of the engineers or other experts, the more valuable will they become in the determination of the award.

This simple proposition is, that the sum to be determined is the difference between the market value of the property under consideration, as it was before the water was diverted, and its market value after the water has been diverted. This is the question, one in simple substraction, which the referees or the jury are called upon to answer. Of course, before this sum in simple substraction can be performed, the referees or the jury have got to arrive at the minuend and at the subtrahend; but any work not bearing directly on the determination of these two, is really not relevant to the work in hand.

I am satisfied that it would be an aid to engineers and to others engaged in these cases in an honest, pains-taking way, to have this idea of market value presented to them, and kept before them in their work. And I am also satisfied that it is a lack of that consideration in the minds of all the parties concerned, which produces so wide variances between claims and final awards, as for instance that found in the case now under consideration; namely, as 160 is to 15; or between claims and admissions.

Referring now directly to the paper of Mr. Hastings, I desire to comment on the columns of the tables which bear on the question of what constitutes freshet water. This is always one of the interesting points in cases of this sort. My own conclusion has been, that on rivers which have been used for water power many years, especially on small rivers and brooks, this question has been answered in the course of years by the experience of the mill owners located upon it. At each mill privilege it has been quite well determined how much wheel capacity it will pay to set up, and whether it would or would not be prudent, and showing lack of business capacity to increase it. Of

course, this supposes no hard and fast rule; nor could this test be applied to a single owner of a single mill privilege, but there are usually a series of such mill privileges within a short distance of each other, on the same stream, each mill privilege held through a series of years, by many owners, of both phlegmatic and of sanguine temperaments, and from the result of their combined experience, as regards a proper and reasonable wheel capacity to maintain on that river, at that point, fully as close a determination can be made, of the quantity which constitutes a proper wheel capacity, and that other quantity which constitutes freshet water, as can be made of any other of the prominent data in the case. It is merely applying the all pervading principle of the "survival of the fittest" to water wheels. On most any river, some mill owner at one time or another, will have run away with the idea that he could get more power out of his property than anybody else could; upon which hard experience will soon have taught him, that it did not pay to have wheels and water connections stand idle so great a part of the year; and the final result will have been an abandoned water wheel. Other mill owners will have failed to fully utilize their water power property; but the concensus of opinion in this regard, among a series of owners during a series of years on the same site, and as confirmed or modified by other series of owners, up stream and down stream from the property in question, is a safe guide to follow.

In this way, I have observed, that very rarely will we find, on any such streams, a wheel capacity greater than would be able to run at full gate, for half the days of the year, the balance of the water during that time wasting over the dam as freshet water; with the wheels taking what they can get, the other half the days of the year. I do not refer to consecutive days of the year, but ranging the flow of the river, on the 365 days of the year, in their order of size, to the first half of the days of the year thus arranged, which will be the 182 or 183 days of largest river flow for the half the days of the year first above mentioned.

More frequently, this limit of commercially practicable wheel capacity is found such, that the wheels have all the water they want, and to spare, for some 243 days of the year, and must needs take what they can get the remaining 122 days. And somewhere between these limits of 182, and of 243 days, as fixing that river flow, which in turn, fixes the commercially practicable and reasonable wheel capacity, to be put in at any mill privilege, is the dividing line, by means of which we are enabled to say, not only for New England streams, but on any mill stream, what constitutes the flow of the river, which may prudently be utilized, and what of necessity constitutes freshet water.

Mr. Freeman. Mr. President, I was very much interested in hearing Mr. Herschel's opening remarks, from the fact that this morning I found lying on my desk a decision lately rendered by the Supreme Court of New Hampshire in a very celebrated water power case, one concerning the water rights in Lake Winnipiseogee, and in looking through that report it struck me most forcibly that the keynote was precisely the same proposition with which Mr.

Herschel began his discussion, viz., that the whole question of damages was to be determined by the fair market value or what a reasonable purchaser would probably pay for the property before the act as compared with the fair market value after the act if it were fairly presented for sale.

As to these tables, I think the most interesting column to the hydraulic engineer is the one marked column VI., showing the actual waste which occurs even during those months of the year when the flow is small. I have seen several times estimates concerning suits for damages made up without any realization of the fact that during even the dry months of the summer there was a considerable proportion of waste. You have a summer freshet, not infrequently an August freshet for instance, during which the water comes down in great volume for a day or two, and during those few days the larger portion of that flood water is wasted; now if taking the record of flow you view the matter simply in the light of a monthly average, as shown in the first column of Mr. Hastings table you get the whole thing smoothed out, and spread over the month raising the general level and so it tends to exaggerate the yield of the stream.

Concerning this question of exaggerating the yield of the stream, it struck me as I listened to the presentation which has been made here, that if a man were to estimate the value of the water power with a view to putting in wheels, or expecting to obtain that power to drive his mill to the amount which has been figured here, he might meet with disappointment.

There are various approximations made in these estimates, nearly all are on the side of the mill owner. That is they all tend to magnify the power a little and the net result of all would be, perhaps, to make the amount of power as shown by the computation anywhere from 10 to 25 per cent. greater than the actual amount of power which could be realized in practice.

For instance, the length of the working hours is here taken as though the water were used for exactly 10 hours per day for six days in the week and was stored for the 14 hours intervening between each day's work.

Now, in point of actual fact such factories commonly run for five days in the week a little over ten hours and a half each day, and so gain a half holiday on Saturday afternoon.

In addition to that, there is always a few minutes' waste of water in starting in the morning and at noon; and above all there is the waste of water which occurs even in the best regulated establishments by the leak of the wheel gates at night. All these things are matters which occur in every day practice. We do not get ideal wheel gates or ideal dams which hold every drop of water which comes into the mill pond at night.

If one is estimating steam power, he adds a certain percentage for the coal which is used in banking the fires at noon and for the starting in the morning. So just in the same way there should be a certain percentage allowed for the unavoidable waste in connection with water power. The water power *is* used *more than ten hours* a day and the fact of running so as to gain the Saturday half holiday tends to accumulate water at the very end of the week when in many cases even the Sunday flow cannot be stored

So as to many other things in the tables. For instance, of estimating the amount of available storage by drawing down a long, narrow pond like that, and assuming that it can at any time be drawn down to the extent of two feet over the whole surface and that all of the water contained in that two feet can be utilized during the working hours. As men practically run water wheels, they seldom do so large an amount of storing as that.

Then there is another point, the percentage of useful effect for the turbine. Almost any turbine maker will guarantee to put in a wheel to furnish 85 per cent. or 80 per cent., and throwing off five per cent. it would seem that 75 per cent. was fair. But there are other things to be taken into consideration. Wheels are not always in first-class condition as practically used, there may be obstructions in the buckets of the wheel, or other little things about the wheel plant which cut down the percentage. But even suppose the wheels were in perfect condition, there is the fact that in utilizing a flow varying so widely, from 67 horse power as the minimum to 128 as the maximum, you are compelled a part of the time to run your wheel under very disadvantageous conditions. So I think that taking things by and as large an average efficiency of 70 per cent. would be a generous statement for the ordinary case.

Mr. Kimball. I have been very much interested, Mr. President, in this paper. I think there is very little in our literature which pertains to this subject in the line that has been presented here this afternoon. I entirely agree with Mr. Freeman in saying that the writer of the paper has been very liberal towards the mill owners in his estimates, and I desire to call the attention of this association to the fact that in the first column, the one which is the basis of this whole table, are figures which have been collected from the reports of the Boston Water Works, which have been kept very carefully for a great many years; and I think every engineer certainly appreciates what a great value those figures are to the profession. It was about twenty years ago while an assistant to Mr. Herschel we were computing the amount of power, and we had no data of this kind, in fact no reliable data by which we could learn the amount of water collectable from a water shed. We could easily measure the water shed, but we could not determine how much of that water could be depended upon for power. I think that the engineers of the Boston Water Works are entitled to a great deal of credit for the figures that they have prepared, which can now be used by engineers in cases of this kind.

Mr. Hale. As bearing a little on what Mr. Freeman has said with regard to running the wheels under different conditions, I would say that in working up the table according to the method which I used, I took the wheels as they actually existed at the time The owners acknowledged that the water power had been developed to the best advantage, that they should never enlarge it any more, and their steam power amounts to about four times what the water power is. So I took their wheels as I found them running, applying the amount of water flowing to the wheels, and seeing under what conditions they could run their wheels to the best advantage, setting them at such points at the gates as would give them the best efficiency, and the computation was worked up in that way, assuming that special attention was paid to that.

Starting from the same figures which Mr. Hastings used in his table, I arrived at about the same results as he did, but from a rather different point of view, taking their plant as they had it, and seeing what was the best use that could be made of the water flowing in the river under the actually existing conditions. And it was pretty liberal to the mills, as we consider it concentrated into ten hours' flow, while without doubt, as Mr. Freeman suggests, there was a great deal of waste at other times which could not be stored.

Mr. Noyes. I would like to ask Mr. Hastings if in making his computation he allowed for the water taken for water supplies from the drainage area above.

Mr. Hastings. No sir.

Mr. Noyes. And for which we have settled with the mill owners for quite a handsome amount. There is Brookline, Dedham, Newton and Wellesley.

Mr. Hastings. No account was made of the reduction on account of water supplies.

Mr. Noyes. It would amount to somewhere from five to eight million gallons.

Mr. Hastings. In view of the whole area of the water shed it would be very small, hardly worth considering, I think.

Mr. Noyes. The mill owners didn't think so.

Mr. Hastings. I would like to say, with regard to what Mr. Freeman has said that in these computations the effort was made to be more than generous with the mill owners, and not as much water was allowed as waste as I should certainly recommend any one who set up a wheel plant to allow for. I should not think it would be wise to set up a plant for more water than would be shown by Mr. Francis' plan of taking the May flow as the maximum amount to be used. With regard to the hours in the day, that varies with different mills, and it seemed impossible to assume any other basis than an ordinary work of ten hours a day, and so that was taken. With regard to the draft on the pond with two feet depth of storage, I did not allow for two feet in depth from the whole pond, but two feet at the dam and tapering up the 5-mile reach, I think, to six inches or one foot in depth, I have forgetten which. Of course it would be impossible to draw the pond down in that length of time level, so we would have the natural hydraulic head, so the pond was not a full pond two feet deep its entire length.

The President. We should be glad to hear from Mr. Charles T. Main.

Chas. T. Main. I think that a few words of explanation as to the great difference in the amount of damage claimed and the amount awarded and the bearing which such amounts have upon the tables presented by Mr. Hastings may be of interest.

The amount of damages as estimated by experts for the plaintiff is usually obtained as follows :

They estimate the average total flow of the stream, including freshet water, and then say if this be taken away, or a portion thereof, it will be necessary to erect, maintain and run a steam plant, complete in itself, of the average power thus taken away, and that the damage is a sum of money which will erect and maintain and run such a plant forever. In this way they figure out enormous sums which usually are absurd.

The method of Mr. Hastings is a method of determining the *average* power which the mills have been deprived of, but it does not tell the whole story as to the manner of estimating the damages.

If the tables were made out showing the average of the dryest months for sixteen years, the next dryest, and so on, instead of the average of the calendar months there would be a greater variation shown in the power. If alongside of this could be seen the monthly average for each year arranged in order of dryness, there would be shown a still greater variation of power, and if finally we could see the daily flow we should discover something which completely overthrows the theory upon which the large amounts were figured out by the plaintiff. We should find that the flow of the river is so variable that it is necessary for a concern which must run constantly to maintain a steam plant of sufficient size to run their machinery independent of the water power.

If, therefore, it be necessary for them to maintain such a plant it is not necessary for the defendants to pay for erecting, maintaining and running a separate plant, and the only loss to such a concern is the extra coal which they must burn to make up for the power taken away and any other incidental increase in running expense which may be incurred.

The effect of this upon the market value of the concern is this. If a man, desirous of purchasing such a concern, knew that a certain amount of water power were to be taken away soon after the purchase, he would ascertain jus what must be done to make this loss good and deduct such a sum from his estimate of value before taking. If he found that no additional plant would be required, but simply a small increase of coal consumption he would decrease the value accordingly.

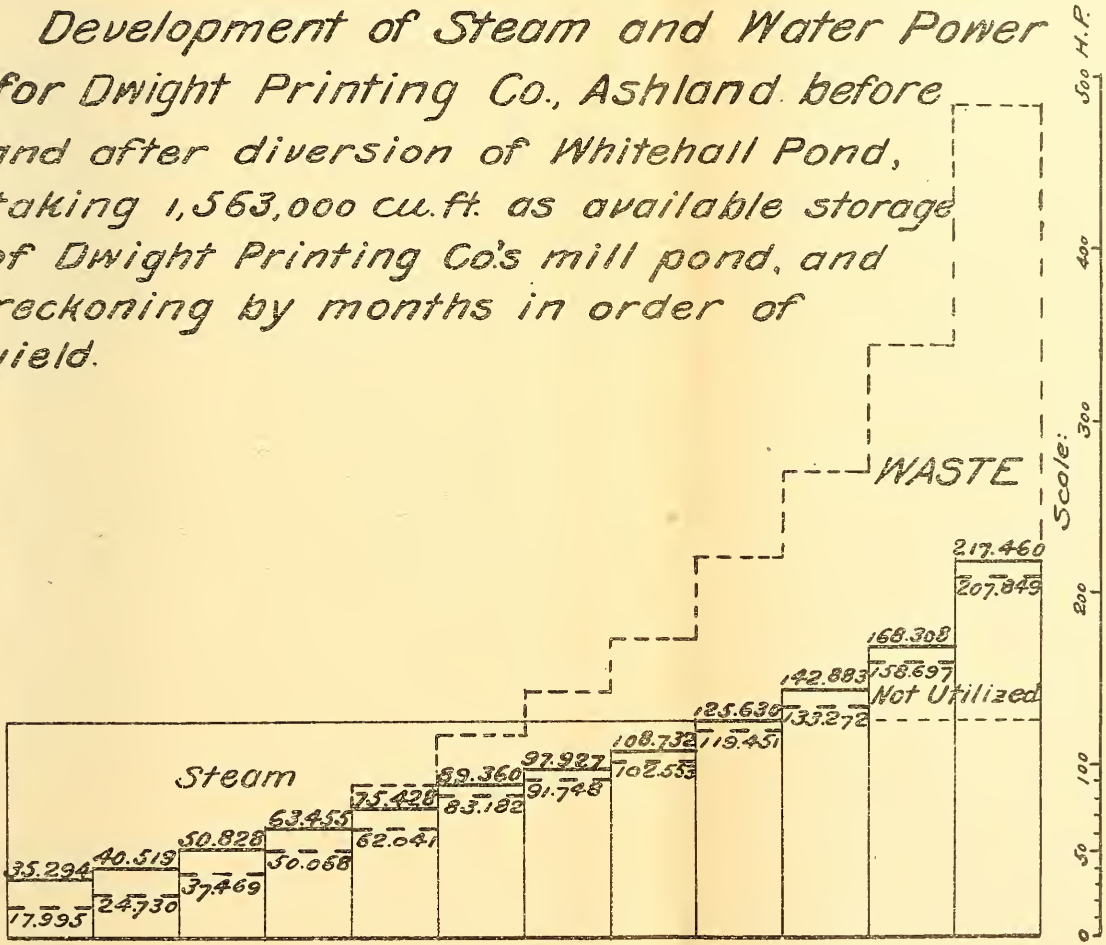
Now it happens to be a fact that in the cases under consideration that those concerns requiring constant power were equipped with steam plants large enough to run their whole works, and the damages as estimated by the defendants were based upon this fact, together with some others, and consequently are much smaller than those of the plaintiff.

The other considerations perhaps have no reference to the paper under consideration, but do affect the market value of the property before and after the taking.

At the Ætna mills the steam plant was large enough to develop the whole power required, and they used all the exhaust steam from their present engines and could use more, so that the cost of producing the slight addition of power would be small.

Desmond FitzGerald
1893

Development of Steam and Water Power for Dwight Printing Co., Ashland before and after diversion of Whitehall Pond, taking 1,563,000 cu. ft. as available storage of Dwight Printing Co's mill pond, and reckoning by months in order of yield.



Available Flow and Power of the Dam of the Dwight Printing Company at Ashland; the present storage is taken as 1,563,000 cubic feet and the net fall is taken as 13 feet.

DESMOND FITZGERALD, CIVIL ENGINEER.

Months arranged in order of dryness.	BEFORE THE DIVERSION OF THE WHITEHALL POND DRAINAGE AREA.												AFTER THE COMPLETE DIVERSION OF THE WHITEHALL POND DRAINAGE AREA.										Effect of the total diversion of the flow of Whitehall Pond drainage area, the extent of probable development of water power being taken as 125.63 H. P. net. (9th No., Col. 13.)		
	Flow per calendar day.							Total flow from Dwight Printing Co.'s Mill Pond.					Flow from the 28.662 sq. m. drainage area.					Total flow from Dwight Printing Co.'s Mill Pond.							
	From the 28.662 sq. m. drainage area (natural flow). Cubic feet.	From the Whitehall Pond drainage area (regulated flow. Cubic feet.	From the total drainage area (33.015 sq. m.). Cubic feet.	Flow for 10 working hours from total area. Cubic feet.	Flow for 14 night hours from total area. Cubic feet.	One-sixth part of the Sunday (24 hour) flow that can be stored. Cubic feet.	Storage that can be added to 10 hour flow. Cubic feet.	Per day of 10 working hours. Cubic feet.	Per month of 25⅓ working days of 10 hours. Cubic feet.	Per month of 30.44 calendar days of 24 hours. Cubic feet.	Flow per calendar month wasted because of insufficient storage capacity. Cubic feet.	Total flow from Mill Pond for 10 working hours reduced to net H. P. (i. e. 75 per cent.) on 13 ft. fall. Horse power.	Per calendar day of 24 hours (natural flow). Cubic feet.	For the 10 working hours. Cubic feet.	For the 14 night hours. Cubic feet.	One-sixth part of the Sunday (24 hour) flow that can be stored. Cubic feet.	Storage that can be added to 10 hour flow. Cubic feet.	Per day of 10 working hours. Cubic feet.	Per month of 25⅓ working days of 10 hours. Cubic feet.	Per month of 30.44 calendar days of 24 hours. Cubic feet.	Flow per calendar month wasted because of insufficient storage capacity. Cubic feet.	Total flow from Mill Pond for 10 working hours reduced to net H. P. (i. e. 75 per cent.) on 13 ft. fall. Horse Power.	Amount of Water Power developed before diversion. Horse power.	Amount of Water Power developed after diversion. Horse power.	Difference, or amount of Water Power lost by the diversion. Horse power.
1	502,516	483,117	985,633	410,680	574,953	164,272	739,225	1.149,905	29,514,228	30,000,000	486,000	35.29	502,516	209,380	293,136	83,753	376,889	586,269	15,047,571	15,295,000	247,000	17.99	35.29	17.99	17.30
2	690,623	"	1,173,740	489,060	684,680	146,387	831,067	1,320,127	33,883,260	35.726.000	1.843,000	40.52	690,623	287,760	402,863	115,104	517,967	805,727	20.680,326	21,021,000	341,000	24.73	40.52	24.73	15 79
3	1,063,670	"	1,546,787	644,490	902,297	110,117	1,012,414	1,656,904	42,527,203	47,080,000	4 553,000	50.86	1,063,670	443,200	620 470	157,088	777 558	1,220,758	31,332,789	32,375,000	1,042,000	37.47	50.86	37 47	13.39
4	1,518,360	"	2,001,477	833,950	1,167,527	65,912	1,233,439	2,067,389	53,062,984	60,920 000	7,857,000	63.46	1,518,360	632 650	885,710	112,882	998,592	1,631,242	41,868,545	46,215,000	4,346,000	50.07	63.46	50.07	13.39
5	1,950,440	"	2,433,557	1,013,980	1,419,577	23,904	1,443,481	2,457,461	63,074 832	74,072,000	10,997,000	75.43	1,950,440	812.680	1,137,760	70,873	1,208,633	2 021,313	51,880,367	59,367,000	7,487,000	62.04	75.43	62.04	13.39
6	2,753,049	"	3,236,166	1,348,400	1,887,766	0	1,563,000	2,911,400	74 725 933	98,501,000	23,775,000	89.36	2,753,049	1,147,100	1,605,949	0	1,563,000	2,710,100	69,559,233	83,796,000	14,237,000	83.18	89.36	83.18	6.18
7	3,422,870	"	3,905,987	1,627,490	(Only	0	"	3,190,490	81,889,243	118,889,000	37,000,000	97.93	3,422,870	1,426,200	(Only	0	"	2,989,200	76,722,800	104,184,000	27,461,000	91.75	97.93	91.75	6.18
8	4,267,780	"	4,750,897	1,979,540	1,563,000	0	"	3,542,540	90,925,193	144,605,000	53,680,000	108.73	4,267,780	1,778,240	1,563,000	0	"	3,341,240	85,758,493	129 900,000	44,142,000	102.55	108.73	102.55	6.18
9	5,589,060	"	6,072,177	2,530,070	can be	0	"	4,093,070	105,055,463	184,822,000	79,767,000	125·63	5,589,060	2.328.770	can be	0	"	3,891,770	99,888,763	170,117,000	70.228,000	119.45	125.63	119.45	6.18
10	6,669,720	751,514	7 421.234	3,092,180	stored)	0	"	4,655,180	119,482,953	225.884,000	106,401.000	142 88	6.669,720	2.779,050	stored.)	0	"	4,342,050	111.445.950	203.010,000	91,564,000	133.27	"	125.63	0
11	8,657,760	"	9,409,274	3,920,530		0	"	5,483,530	140,743,937	286.394,000	145,650,000	168·31	8,657,760	3 607,400		0	"	5,170.400	132.706,933	263,520,000	130,813,000	158.70	"	"	0
12	12,501,100	"	13,252.614	5,521,920		0	"	7,084,920	181,846,280	403,376,000	221,530,000	217 46	12,501,100	5,208,790		0	"	6,771.790	173,809,277	380,502,000	206,693,000	207.85	"	"	0

At the Waltham Bleachery there is a fall of only four feet. This has not been developed for power and no one would think of doing so at the present day. The loss to them of *power* is therefore nothing.

At Hollingsworth & Whitney's the use of water power has been abandoned oweing to the fluctuation of power and other reasons.

The powers at Perkins' grist mill and Walker, Pratt & Co., are not only affected by the variable flow of the stream but also by the tide, thus making an extremely variable power. How such power can be considered of equal value to a constant steam power I cannot conceive.

After having obtained the average power which is taken away it is necessary to know the variation in the flow of the stream and the local conditions for each property which is deprived of such power before it can be determined what the approximate decrease in market value would be.

Mr. FitzGerald. Mr. Hastings' paper has interested me very much. It has been my lot to have been engaged in a number of similar cases in the past few years. While no case arises in which something is not to be learned yet the figures of damages are often amusing especially where based on the average flow of the stream. In the well known Whitehall pond case which has just been tried before commissioners I presented in behalf of the city of Boston the following table and diagram which I think shows the effect of a diversion of a stated quantity of water daily from a stream. Whitehall pond is a tributary of the Sudbury river and by my estimate it is capable of yielding 483,117 cubic feet daily.

The question was what effect this diversion would have upon a mill situated some distance down stream, in fact a number of miles below the junction with the main stream. The table exhibits so clearly the process of reasoning that it will be unnecessary for me to go into the details. I think for the first time the *necessary* waste, in the case of a development of power to the 4th month and the waste from lack of power to use the water, are shown. It will be evident to any one accustomed to the usual methods of developing water power that a reduction could very well have been made for water wasted in various ways at the wheels, but in this particular case it was not thought wise to make this subtraction, it being the intention to give a liberal estimate of the amount of water that could be used or *available power*. The diagram shows what an enormous amount of waste occurs even with a mill pond of considerable capacity and where a very high development of wheel power is assumed.

STAND PIPES AND THEIR DESIGN.

BY

Freeman C. Coffin, C. E., Boston, Mass.

There has been very little written upon the subject of stand pipes, in consideration of their importance in water works construction and their great and growing use.

The literature of the subject is extremely scanty. I do not know of any book upon it nor have I been able to find any treatment of it in any general work on water works construction.

There are a few good papers and some writing of a fragmentary nature.

Mr. John F. Ward has an article in the Engineering News of July 24, 1886, which contains many practical ideas in relation to construction.

Mr. A. H. Howland read a paper before the Engineers' club of Philadelphia, in 1887, in which he made some valuable suggestions and gave a table of minimum thickness of top plates and other dimensions.

Mr. B. F. Stephens read a paper before the American Water Works Association which is published nearly in full in the Engineering News of October 6, 1888. This paper contains a discussion of several failures and also a valuable statistical table of many stand pipes in use. The table was published in the Engineering News of October 13, 1888.

The Engineering Record in the issues of April 25 and May 2, 1891, published in full a paper read by Mr. W. Kiersted before the Rensaelaer Society of Civil Engineers some time before. In this paper is a theoretical discussion of the strains upon a stand pipe with several formulæ and a useful table of rivets and spacing. I shall refer to these papers in my discussion of the subject.

There are one or two other papers of which I have seen the name, but had not the opportunity to consult them.

The first question in the design of a stand pipe is the size, the element of height coming first, and this is largely determined by natural conditions. It is not within the province of this paper to discuss the head required to provide suitable fire streams, for that question is decided quite independently of the stand pipe, and when that is fixed in any particular case, the topography of the locality will determine the height or length of the stand pipe.

In a hilly country it must be a compromise between a heavy pressure in the low portions and a light pressure on the hills.

In this section an elevation can usually be found where it need not be of excessive height in order to give a satisfactory pressure over the greater part of the territory to be served ; but different conditions prevail on the level lands of the west, and the influence of these is seen in the types of stand pipes built in the different sections. In the eastern states the present tendency is toward a stand pipe, or more correctly, a tank of large diameter, whereas on flatter country they are nearer what the name implies, a *stand pipe* or water tower, with great height and small diameter, the result of the ne-

cessity of obtaining sufficient head, combined with the desire for small expenditure.

I believe that the height, as it is the first element to determine upon, has also been generally considered the most important, and the holding capacity has nearly always been rated as the area of cross-section multiplied by the entire length or height, with the result of building a tall pipe of small diameter and vice versa. A desire for saving in first cost also tends in the same direction.

But where the subject is examined rationally it will be seen, I think, that the question of diameter is almost entirely independent of that of height. The efficient capacity must be measured by the length from the high water line to a point below which it is undesirable to draw the water on account of loss of pressure for fire supply, whether that point is the actual bottom of the stand pipe or above it. This allowable fluctuation, I should say, ought not to exceed 50 feet in most cases in a well designed system. This makes the diameter dependent upon two items, the first of which is the amount of the consumption during the ordinary interval between the stopping and starting of the pumps. This should never draw the water below a point that will give a good fire stream and leave a margin for still further draft for fires.

The second item is the maximum number of fire streams and their size, which it is considered necessary to provide for, and the maximum length of time in which they are liable to have to run, before the pumps can be relied upon to reinforce them.

Diagram No. 2 gives the number of feet which water in tanks of different diameters will be lowered by different populations using 60 gallons per head per day with the pumps running 8 and 10 hours in the day time, and being stopped at night.

This raises the question of the relative draft at different times of the day, and it would be of great value if data could be collected and examined to show the ratio of maximum and minimum draft per minute to the average draft per minute for the entire day. The last is easily found from the pumping records, but the writer recently having need to know approximately the maximum draft, could find no figures relating to it.

Through the kindness of Mr. Byron I. Cook, superintendent of the Woonsocket Water Works, where there is a recording pressure gauge on the stand pipe, I obtained the cards for one month, and computed the maximum hourly flow for each day. This case as you may see on diagram No. 5, plotted from one day's record, gives the hourly maximum 86 per cent. greater than the daily average. The average draft per minute from 6 p. m. to 7 a. m. was but 46 per cent. of the average daily draft per minute, and this was used as the basis of calculation for diagram No. 2. This was but one day in one city, but you may see that the daily average is close to the monthly average by reference to the diagram.

Diagram No. 3 shows to what depth any number of fire streams of 200 or 250 gallons per minute will draw the water in tanks of different diameters in one hour, which should be the maximum time before the pumps can reinforce the tanks.

There is another reason for making the diameter large, and that is to provide for stability against wind pressure when empty. The writer has seen a tank 30 feet in diameter and 113 feet high lifted $\frac{3}{4}$ of an inch from its foundation on one side, by the force of a strong wind, but not one of the strongest winds we have in this section.

The following table gives the height of stand pipes beyond which they are not safe against wind pressures of 40 and 50 lbs. per square foot. Area of surface taken is the height $\times$ $\frac{1}{2}$ the diameter on account of the cylindrical form.

Table of heights of stand pipes that will resist wind pressure when empty by their weight alone.

	Wind of 40 lbs. per sq. ft.	Wind of 50 lbs. per sq. ft.
20 feet diameter,	45 feet high.	35 feet high.
25 " "	70 " "	55 " "
30 " "	150 " "	80 " "
35 " "		160 " "

To have the above degree of stability, the stand pipes must be designed with the outside angle iron at the bottom connection as shown in Fig. 1, plate 6.

I consider any form of anchorage that depends upon connections with the side plates near the bottom, as unsafe. If attached at points on the side plates, as all forms of brackets and holding down bolts are, a strain comes upon the plate that it is not usually designed to bear, in addition to the strain caused by the water pressure, although it may be said that both strains will not come together. But aside from that, the strain which the wind pressure brings upon the horizontal joints is not lessened by this method which holds the bottom to the foundation, and leaves the rest of the pipe to resist the wind as a cantilever, whereas by suitable guys the wind pressure is resisted by tension in the guys, and the stand pipe is relieved from wind strains that tend to overthrow it. The guys should be attached to a band of angle or other shaped iron that completely encircles the tank, and rests upon some sort of bracket or projection, and not be riveted to the tank. They should be anchored at a distance from the base equal to the height of point at which they are attached, if possible.

The best plan is to build the stand pipe of such diameter that it will resist the wind of its own stability.

The foregoing suggests that a tank might be elevated upon a foundation or base, as the top 50 feet is all that will give the proper efficiency as storage capacity, and in fact, this has been done in some cases, and this part of the subject will be touched upon in the latter part of this paper.

The height and diameter having been decided upon, the material of which to build is the next point to be considered. Stand pipes are built successfully both of iron and steel, and I suppose the final word cannot yet be said in regard to the comparative merits of the two, everything being considered, but it may be a suggestive fact that all or nearly all failures have been of steel, unless I am misinformed. This may be due only to poor design or

construction, which it certainly was in some cases. This brings up the subject of failures and their causes, and I will mention a few of the noteworthy ones.

There have been a number of remarkable failures of stand pipes in the United States within the past ten years.

Defiance, O. This was one of the later failures, and occurred March 29, 1891, and was fully described in the Engineering Record of April 11, 1891. This pipe was 22 feet in diameter and 140 feet high, built of steel, with the lower ring $\frac{5}{8}$ inches thick; strength of material not stated, but to have a factor of 3 at the joints, it should be 65.000 lbs. ultimate T. S Upon water being first let into the tank, a leak was discovered, and it was found to be from a crack between the vertical rows of rivets in a plate in the second ring from the bottom. The sediment in the water soon stopped the leak, and nothing was done about it. On the morning of February 8, the gauge showed 60 feet of water in the tank or 80 feet below top, and upon starting the pumps, the engineer heard a loud report and saw ice thrown 10 feet above top of stand pipe. and it rocking violently Upon investigation, another crack was found in the same sheet, near the opposite end, from a rivet hole, and about six inches long. The leak stopped as before, and the pipe was used until March 29, when it burst, wrecking itself, and the engine house near by. Should say the cause was a poor sheet, combined with gross carelessness in its continued use.

Senaca Falls. N. Y. This pipe, which burst in 1887, was 130 feet high and 30 feet in diameter, of steel plates $\frac{5}{8}$ inches thick in lower ring, with 50,000 T. S. The lower ring should have been 1 inch thick to have a factor of 3 at the joints. The steel was said to be a coarse, poor grade, as indicated by the fractures. The foundation of this pipe, which weighed full about 3000 tons or $4\frac{1}{4}$ tons for each square foot of the bottom, was said to be of the poorest description.

I think there is no doubt that this pipe was built of too thin plates. The Engineering Record gives the strain on the plates between rivet holes as 23,000 lbs. per square inch and on the rivets as 25,000 lbs. per square inch, which I find is the case figured from the dimensions given. This is .5 of the ultimate strength of the plate and .6 of the shearing strength of best rivets, leaving a small margin against chances of defects in work or material.

On the same day as the above, a stand pipe in Franklin, Mass., fell from its pedestal. This tank was 40 inches in diameter, and 35 inches high, with $\frac{3}{8}$ plates at the lower ring. The plate seems to be of sufficient thickness, and the failure was in the pedestal or foundation, caused by filling the tank before the masonry was dry. The base was of brick masonry 45 feet high and 35 feet in diameter outside, of two rings of brickwork, the outer 16 inches thick, and the inner 12 inches, and 12 feet in diameter. The bottom of the tank was supported by iron I beams. The pressure per square foot on the brickwork with the tank full would have been 7.8 tons. With the amount of water in it when it fell, it was about 5.6 tons per square foot. A detailed

description of these two failures may be found in the Engineering Record, November 5-12, 1887.

Gravesend, N. Y. Perhaps the most remarkable of all failures was this one in October, 1886. Certainly it was a remarkable stand pipe. Its total height was 250 feet, diameter for 70 feet of the lower portion 16 feet, the frustrum of a cone from 70 feet to 95 feet from the base, where its diameter was 8 feet, which size it held to the top, 155 feet more. The first five feet were of $\frac{7}{8}$ inch plates; the next 30 feet of $\frac{3}{4}$ inch and growing thinner to the top where it was $\frac{1}{4}$ inch. The thickness seems ample, if the metal were good. The Engineering News stated that the appearance of some of the bottom plates indicated poor and brittle metal. I think Mr. John F. Ward has attributed the failure to the right cause, which was that the top was drawn in, creating a tendency in the pressure of the water on the under side of the conical portion to lift the sides from the foundation, which it is reported to have done at first filling, when there were two rings of braces, of 24 in each ring, put inside and riveted or bolted to the sides and bottom, to prevent the sides from rising, or in other words, the bottom from bulging outward. Mr. Ward's letter may be found in the Engineering News of November 13, 1886. His figures are total pressure on the bottom of 1448 tons; total weight of water, stand pipe and fixtures, 855 tons, leaving a lifting force of 593 tons. I figure it a little differently. The total lifting strain equals the difference in area of the two diameters 8 and 16 feet or 151 square feet $\times$ the average pressure on the under side of cone or 5.23 tons per square foot equal 790 tons total pressure. To oppose this lifting force, there is the weight of the water in the annular space under the cone, plus the weight of the sides of stand pipe, about 440 tons in all, leaving 350 tons to be carried by the braces to prevent the bottom from bulging. The total strain will come at first on the inner ring or long braces, 24 in number, making 14.6 tons on each brace. Their section was $2\frac{1}{2}$ inches $\times$ 1 inch with probably a loss of at least 1 inch for rivet and bolt holes, leaving $1\frac{1}{2}$ square inches effective section, or a strain of nearly 10 tons per square inch or 20,000 lbs. The braces being an after thought, may have been ordinary rolled bars of a low tensile strength, and it is more than likely that they were attached in such a manner as to bring the strain that two should have carried upon one in some cases, which giving away, as Mr. Ward says, brought a shock upon the plate to which it was fastened, that was too much for its strength and rupture followed.

The whole design of the stand pipe was most absurd. To save weight probably it was made smaller at the top where the plates were light, and left large at the bottom, where the plates should be as heavy as if the full diameter were carried to the top; saving at the spigot and wasting at the bung, and the storage capacity reduced at the top where needed, and maintained at the bottom where it was not available. In fact the stand pipe was upside down. It was this that suggested the form of structure shown on plate No. 7 which is this one inverted, with the proportions changed. This failure was described in the Engineering News and Engineering Record.

I will mention one stand pipe that was overthrown by the wind, that at Kankakee, Illinois. It was 20 feet in diameter, and 124 feet high; first ring 11-16 inches thick, which was ample, with good metal. The top plates were too thin, being but $\frac{1}{8}$ inch and were, in my opinion, the cause of the accident. The tank was anchored by six $1\frac{1}{2}$ inch bolts, fastened to the second ring of plates, and passing down into the foundation. It was empty at the time; velocity of wind estimated at 60 miles per hour.

The weight of the tank multiplied by its leverage, $\frac{1}{2}$ diameter, was less than the wind pressure by *its* leverage, $\frac{1}{2}$ the height, and the excess came upon the rods, straining them, according to my figures, from 5 to 10 tons per square inch, with wind pressure of 20 to 30 lbs. per square foot. This was in a normal condition, but when the top collapsed and formed a pocket, at once doubling the effect of the wind on that portion, and throwing the increase all upon the rods they parted, and the pipe fell.

But to return to our subject. There seem to be reasons for the use of steel in boilers, that do not exist in stand pipes. As I understand, it is desirable to keep the plates in boilers as thin as possible to prevent burning, and this the higher tensile strength of steel accomplishes. Steel is also said to be less liable to blister than iron, on account of the different structure of the two. I have been able to find no discussion on the comparative merits of the two materials in the construction of stand pipes. but of the above reasons for using steel for boilers, neither apply to stand pipes, and in fact, the extra thickness required in iron owing to its lower tensile strength, is an advantage, for as far as I know, iron rusts no faster than steel, nor thick plates faster than thin, and the loss is a smaller percentage of both thickness and strength in thick plates than thin. But the question of cost rules all things, and as I am told good steel can be furnished at least 25 per cent. less cost than good iron, if it can be shown that it is a safe material to build with, as probably a mild steel is, if properly proportioned, the majority of pipes will be built of that material.

The next element is the thickness of the side plates. There are many formulæ, more or less complex but it seems to me a simple question. The pressure on the sides is outward, and due alone to the weight of the water or pressure per square inch (I refer now to strain tending to rupture the plates vertically) and increases in direct ratio to the height and also to the diameter. The strain upon a section 1 inch in height at any point, is the total strain at that point, divided by two, for each side is supposed to bear the strain equally. The total pressure at any point is equal to the diameter in inches, multiplied by the pressure per square inch due to the height at that point.

It may be expressed in a formula as follows:

Let H=height in feet
" f=factor of safety.
" d=diam. in inches
" p=pressure in lbs. per square in.
" $.434=p$ for 1 foot in height.
" s=tensile strength of material per square inch.
" T=thickness of plate

*then total strength on each side per vertical inch

$$= \frac{.434Hd}{2}$$

$$\text{or} = \frac{pd}{2}$$

$$T = \frac{.434Hdf}{2s} \qquad \text{or} = \frac{pdf}{2s}$$

There is one element in the above formula to be decided and one of the most important, i. e. what value to give f. This is of course a matter of judgment, but there is one point to be settled before we can use our judgment intelligently. It seems to be the general custom in boiler construction to define the factor of safety in terms of the tensile strength of the plate, as a factor of 5 for 50,000 lbs. iron, would give 10,000 lbs. as the safe strength but a moment's reflection will show us that as the joints are the weakest point in the construction, it is to them that we must look for the safe strength of the work, and we must first find the strength of these, which is dependent upon the strength of the plate, and when found may be expressed as a percentage of the strength of the whole plate, and then we may denote our factor in terms of the tensile strength of the plate, if more convenient, for we shall then know what we mean by it, and shall not be deceived by a high nominal factor of safety.

Some experiments with specimens of riveted joints show as high as 60 per cent. of the strength of the plate for single riveting and 75 for double. Fairbairn gives respectively 56 and 70 per cent. including friction in the joint. Of course the experiments with riveted specimens new and made for the purpose include the friction, but I do not think it is safe to rely upon it at all in stand pipes. When first built, and empty, they are not quite round; generally when filled, the water forces them into circular shape, and some of the joints must start a little. It is a fact that they do, and cause leaks; this would destroy the friction in these joints. Again, the joints are liable to rust between the plates where they cannot be painted; this would destroy the friction. Therefore it seems safe to disregard it, and compute the strength of the joint from the section of plate between the holes, and the shearing strength of the rivets. The crippling strength of the rivets need not be considered, as it is higher than the shearing strength in all dimensions of rivets and plates used in stand pipes. The aim must be to make the strength of the untouched plate equal to the shearing strength of the rivets.

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*Note error in formula in diagram No. 1.

I have calculated the joints on this basis in plates from $\frac{1}{4}$ to 1 inch in thickness, with different sizes of rivets and spacing of the holes, and as a result have designed a table of dimensions, which gives the highest results I could obtain. In these calculations I took the safe strength of the plate as 10,000 lbs. and strength of rivets in single shear as 7,500 lbs. The plates not only lose the metal in the holes, but the remaining metal is weakened by punching.

Prof. C. H. Benjamin, of Case Scientific school, recently described some tests of steel before the Civil Engineering club of Cleveland, where he found this loss to be 7.5 per cent. for punching over drilling as a mean of all his tests. He found that the loss due to the use of a spiral punch was only 3 per cent.

I find in a book on boilers by W. M. Barr, a series of tests of steel by Kirkaldy, in which the deterioration is 9.5 per cent.

In the same book are some tests of iron by Hooper and Townsend. In these the punched bars showed greater strength than drilled ones. They claim that the result was due to the use of a punch that accurately fitted the die, instead of having the die larger, leaving a conical hole, as is usual, their theory being that the plate is subjected only to direct vertical pressure, with no tendency to lateral or bursting strains, with punch and die the same size.

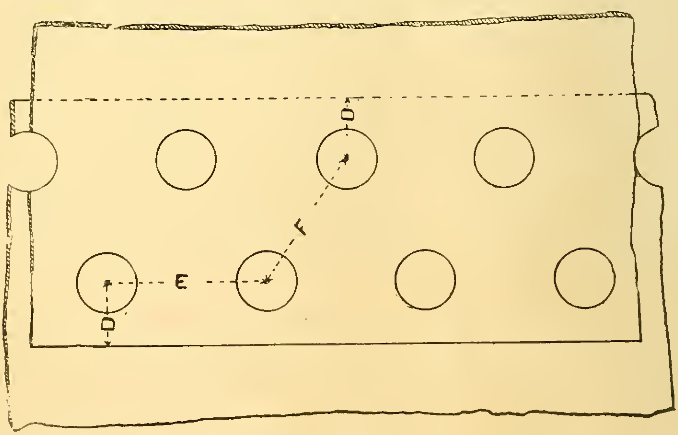
Mr. Barr also claims superiority for the spiral or shearing punch, with tests of bars punched with both spiral and flat punches, one hole of each in each bar, the bar broke through the hole of the flat punch each time.

In my calculations I assume a loss of 8 per cent. beside the loss of metal. In the right hand column are the percentages of strength of the joints in relation to the strength of the plate, which range from 59.5 per cent. in 1 inch plates to 65.5 in 5-16, for double riveted joints, and 70 per cent. for triple riveted joints in 1 inch plate. It would be better to use triple riveting than to exceed 1 inch plate.

The dotted line C. D. on diagram No. 1 shows to what height stand pipes of different dimensions may be built of 50,000 metal without exceeding 1 inch if triple riveted, and the dotted line A. B. on the left of the same diagram shows at what distance from the top of the stand pipes single riveting is sufficient in vertical joints. The percentage of strength in joints is in inverse ratio to the thickness of the plates as shown by the table. Taking this table as the basis, I assume that it is safe to use 60 per cent. of the strength of the iron as the strength of any double riveted joint, but all plates above $\frac{3}{4}$ inch should be drilled instead of punched. Using a factor of 5 for strength of whole plate, or a nominal factor, as it may be called, will give us an actual factor of 3 at the joints for the strength of the work.

TABLE OF RIVETS AND SPACING.

	Thickness of Plate	Rivets Diam.	Length	Center to Edge of Plate	Center to Center of Rivets	C to C of Rows Diagonally	Per Ct of Strength of Whole Plate	
	A	B	C	D	E	F		
Single Rivet	$\frac{1}{4}$	$\frac{5}{8}$	$1\frac{1}{4}$	1	$1\frac{11}{16}$		54.5	Punched
" "	$\frac{5}{16}$	$\frac{11}{16}$	$1\frac{1}{2}$	1	$1\frac{11}{16}$		52.5	"
Double "	$\frac{5}{16}$	$\frac{5}{8}$	$1\frac{1}{2}$	1	$2\frac{1}{4}$	2	66	"
" "	$\frac{3}{8}$	$\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{16}$	$2\frac{5}{8}$	$2\frac{1}{8}$	66	"
" "	$\frac{7}{16}$	$\frac{13}{16}$	2	$1\frac{1}{4}$	$2\frac{3}{4}$	$2\frac{1}{4}$	64.7	"
" "	$\frac{1}{2}$	$\frac{7}{8}$	$2\frac{1}{4}$	$1\frac{3}{8}$	$2\frac{7}{8}$	$2\frac{7}{16}$	63	"
" "	$\frac{9}{16}$	$\frac{15}{16}$	$2\frac{1}{2}$	$1\frac{1}{2}$	$2\frac{15}{16}$	$2\frac{9}{16}$	63	"
" "	$\frac{5}{8}$	1	$2\frac{3}{4}$	$1\frac{9}{16}$	3	$2\frac{3}{4}$	62	"
" "	$\frac{11}{16}$	$1\frac{1}{16}$	3	$1\frac{5}{8}$	$3\frac{1}{8}$	$2\frac{7}{8}$	61	"
" "	$\frac{3}{4}$	$1\frac{1}{8}$	$3\frac{1}{4}$	$1\frac{3}{4}$	$3\frac{1}{4}$	3	60	"
" "	$\frac{13}{16}$	$1\frac{1}{8}$	$3\frac{3}{8}$	$1\frac{3}{4}$	$2\frac{7}{8}$	$2\frac{7}{16}$	61	Drilled
" "	$\frac{7}{8}$	$1\frac{1}{8}$	$3\frac{1}{2}$	$1\frac{3}{4}$	$2\frac{7}{8}$	$2\frac{7}{16}$	59.3	"
" "	$\frac{15}{16}$	$1\frac{3}{16}$	$3\frac{3}{4}$	$1\frac{7}{8}$	3	$2\frac{3}{4}$	59	"
" "	1	$1\frac{1}{4}$	4	$1\frac{15}{16}$	$3\frac{1}{8}$	$2\frac{7}{8}$	59	"
Triple "	1	$1\frac{1}{8}$	$3\frac{3}{4}$	$1\frac{3}{4}$	4	$3\frac{1}{2}$	70	"



Mr. Howland in his paper, places the strength of the joint at 75 per cent. in double, and 66 per cent. in single riveting, based upon government test. I presume this includes friction. He however, advocates a factor of 4, which would make the joints equal to a factor of 3.2 on basis of 60 per cent.

The vertical joints require more care in design and workmanship than any other portion of the structure, and the *rivet iron should be of the best quality.* The strain upon the horizontal joints is caused by the weight of metal above the joint, and is small in proportion to the strength of the joint, and by the pressure of the wind in its tendency to overturn the tank, which would only come upon the tank when it was empty, or partially so, and as I regard it, would not be added to the strain caused by weight of metal.

The amount of the wind strain per square inch of metal at any joint, can be found by the following formula, in which

H=height of stand pipe in feet.
T=thickness of plate in inches.
w=wind pressure per foot in height above joint.

$w=\frac{Dp}{2}$ where D=diameter in feet.

p=wind pressure per square foot.
m=average leverage or moment about neutral axis or central points in the circumference.
or m=sine of 45° or .707 times the radius in feet.

then strain per square inch of metal of plate $=\frac{H^2w}{2\text{ (circ. in ft.) }mT}$

I have not had time to work out a diagram of strains caused by wind pressure as I should like to have done, but with wind pressure of 40 lbs. per square foot all pipes built of thickness called for by diagram No. 1 up to 30 feet in diameter, are amply strong with single riveted horizontal seams if not higher than the limit given in the list of stability against wind pressures, and if properly secured by guys, will be all right for any height. A 30 foot stand pipe should be double riveted in the horizontal seams below 100 feet from the top. Pipes 35 feet in diameter and over, will be safe with single riveted horizontal joints, up to the limit of 1 inch bottom plates at least.

The only other strain to be provided for is the wind pressure tending to collapse the top. Mr. Kiersted gives in his paper a formula to find the thickness of plates to resist this, but says it is a crude and approximate method. I think it must be left to the judgment.

On the diagram for thickness where the full oblique lines change to dotted oblique and full vertical lines, is indicated the thickness of the top for different diameters. The top plates should never be less than these vertical lines indicate, and must be thoroughly reinforced by a heavy angle iron, well riv

eted to the plates at the top, and encircling the tank. The length of the full vertical lines, shows how far down from the top, this minimum thickness may be carried.

This diagram, which is on the left hand of the large diagram No. 1 gives total strain on a 1 inch vertical section of side plates for all diameters shown on oblique lines and all heights to 160 feet. The scale of strain is given at the bottom. It also shows the thickness required at any point with material of 50,000 lbs. T. S. with nominal factor of 5, equal actual factor of 3 at joints. The scale of thickness in sixteenths of an inch given at the top. I have made inquiries and calculations to find by what fraction of an inch it is most economical to change the thickness of side plate, and find that it pays to reduce by sixteenths, and it does not pay to make the reduction less than that. The thickness of plates may be read directly from the diagram, and the fraction of a sixteenth should be added rather than taken off when the thickness does not come on the line. The scale of height is divided every five feet, as that is the common width of plate, but other widths may be taken by estimation or by scale.

There is no strain upon the bottom plates when resting upon a solid foundation, and the thickness must be left to the judgment. It must be sufficient to caulk properly to resist the pressure of the water, and also to allow for corrosion on the under side. In computing the diagram of weight, I used bottom plates approximately 75 per cent. of the thickness of lower ring of side plates in each case.

I think there are no other elements in the general design. Matters of detail must be largely left to individual taste. The bottom connection with sides is important; Fig. No. 1, plate 6, shows the most desirable form; this brings the weight of the sides well in upon the foundation, and also gives greater stability against wind pressure.

The side rings are generally made larger at the top to allow the caulking to be done on the outside of the stand pipe and on the top edge of the plate in the horizontal seams. Sometimes the rings are the same size at top and bottom, and every alternate ring is inside of the one next above and below it. This is not quite as convenient in caulking, but the tank is more likely to be true and round, and has a neater appearance. Perhaps the most difficult work in erection is the beating down of the edges of the plate where three thicknesses meet. In thick plates, this is very difficult, and they have to be heated in place by a basket fire to do it, and when finished an unsightly spot is left at the joint. I think a better method would be to make the joints as shown in Fig. 5, plate 6. The rings alternate in and out, and only the horizontal joints are lapped; the vertical joints are made with butt straps as shown in the figure; this avoids beating down the plates as they are butted at the vertical joints. Although there would be a small increase in weight of metal and of riveting due to the butt straps, yet it would result in a material economy in a pipe with plates over ½ inch thick, and improve its appearance. The caulking should be done on the outside except on the bottom where the outside cannot be reached.

In a cold climate there should be no bars, braces, pipes or ties inside the stand pipe. A light ladder seems to be a necessity, but it should be as plain as possible, and truly vertical.

Diagram No. 1 giving the cost and weight of stand pipes from 20 to 100 feet in diameter and up to 160 feet high was computed and plotted on the basis of design suggested in this paper. Ten per cent. was allowed on weight of all iron work for laps and rivets, and excess of metal over the standard thickness. This would not cover the loss from shearing down plates that were not rolled to the right size, but I believe they come from the mill cut to order. The changes in thickness was made by sixteenths of an inch, and the weight of each diameter carefully computed for every 10 feet in height, and includes the bottom and angle iron. The cost is figured at 5 cents per pound erected and painted inside and out, 3 coats. This will cover the cost built of best iron at the present time, of tanks whose total weight is not less than 50 tons; for weights less than this, the cost might be higher; but contract prices vary from time to time, and it is only claimed for the diagram that as close an estimate may be taken from it as can be obtained in any other way, and if the market warrants a different basis than 5 cents per lb., the result obtained from the diagram may be multiplied by the proper ratio. If a balcony is required, the table of cost at bottom of diagram gives the cost for different diameters of stand pipe of a plain balcony with hard pine floor. Ladders will cost approximately 50 or 60 cents per lineal foot, and spiral stairs may be built in a neat, plain style for about $5 for each step including hand railing. The weight and cost are reprosented on the diagram by curves from the upper left hand corner. The capacity in U. S. gallons is represented by oblique lines from the upper right hand corner, The scale of weight and cost is at the top of diagram, and of capacity at the bottom. Diagram No. 7 gives the cost of good cement rubble masonry foundations, with granite coping 12 inches deep all around. Three different scales give the cost at $4, $5 and $6 per cubic yard including earth excavation. These prices probably cover the extreme limits in different localities.

With underground water supplies, it is necessary to cover the stand pipe. A good form of roof is a conical one made of plates $\frac{1}{8}$ inch thick lapped and riveted, and attached by iron clips to the angle iron at the top of the stand pipe, also to a sufficient number of interior horizontal ribs of angle iron to give it resistance to the wind. Plate No. 7 shows the general appearance of this form of roof, and diagram No. 8 gives weight and cost of it if built without ornamentation. Two scales give the cost at 8 and 10 cents per lb., the latter price being probably the safer.

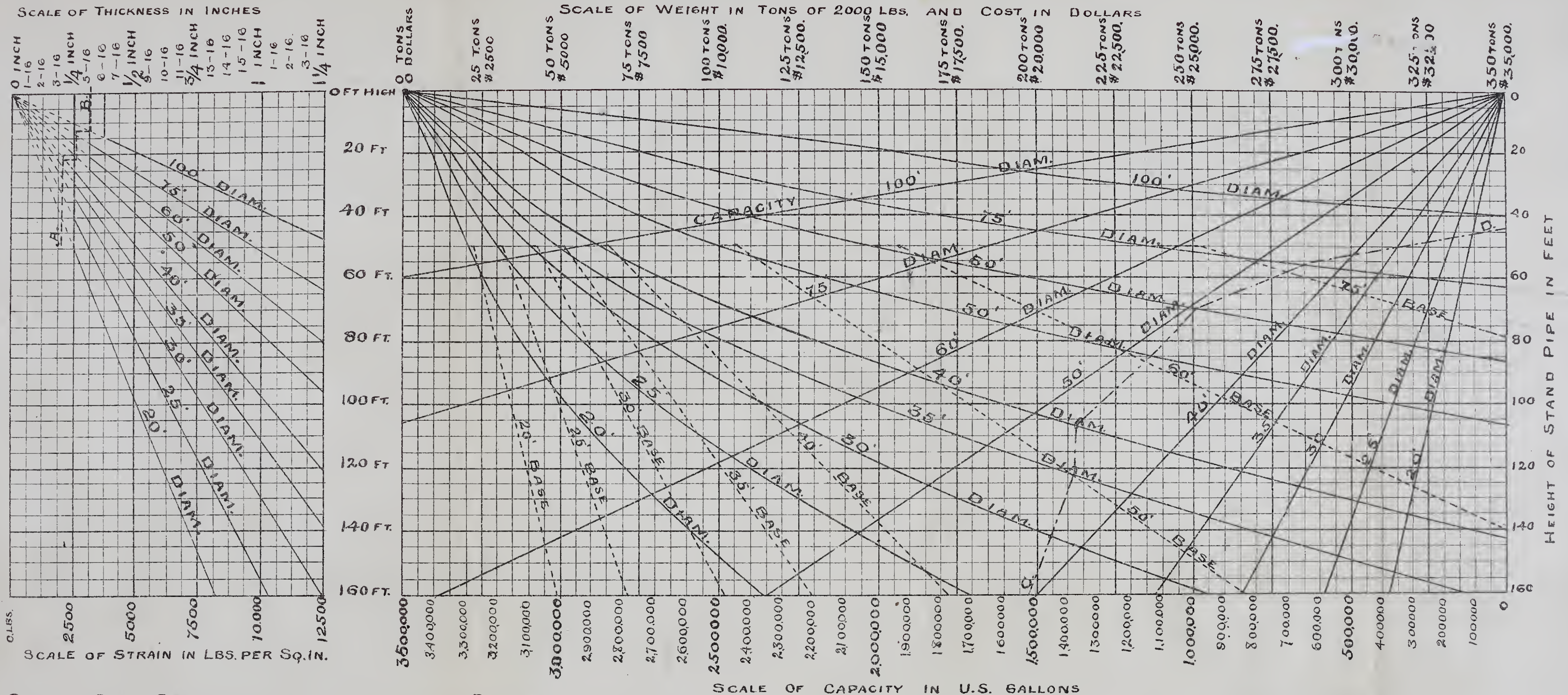
From the diagrams given with this paper, estimates of cost of stand pipes of the design and sizes given, with all parts of the same, may be taken in a few minutes, that will be as close as any that may be made with hours of computation or obtained in any way except by actual bids.

ELEVATED TANKS.

I should like to notice a number of elevated tanks that have been built, but this paper is already much longer than I intended it to be, and I will just speak of the Norton water tower of the Liverpool Water Works, and a form proposed by Johnson & Fladd, civil engineers. The Norton tower is an immense tank or basin of mild steel 82 feet diameter, with vertical sides about 10 feet high, with a bottom in the shape of an inverted dome, 19 feet deep. This is supported by a tower of stone masonry, the whole making a handsome structure about 125 feet high. A full description of this remarkable tower may be found in the Engineering Record of October 3, 1891.

The form of tank proposed by Messrs. Johnson & Fladd is illustrated and described in the Engineering News of August 15, 1891. This form of tank has an inverted dome shaped bottom, and is elevated upon a base of steel columns, and makes a pleasing design at reasonable cost.

Plate No. 7 shows an elevated tank in which no claim is made of originality in any of its parts, but the whole design is somewhat different from any I have seen, and seems well adapted to economical construction. The bottom is conical, which avoids the necessity for support, except at the point where it is connected with the sides, and is less expensive to construct than a spherical form. The plates where they connect with the sides should be the same thickness as the lower ring of side plates, and may be reduced in thickness toward the centres, where the supply pipe enters, through a stuffing box of composition, a detail of which is shown on plate 6, Fig. 4. The base is of steel, Z bar columns, of which a section is shown in Fig. 3. plate 6, well braced and counter braced to resist the wind pressure. The outside line of the columns is a parabolic curve, made up of sraight lengths of the columns. The drawing shows them in lengths of 20 feet, but they may be made shorter with a little more expense for bracing if necessary to make a smoother curve. This form of column is well adapted to this work, as the connections are so easily made, and the whole surface is exterior and accessible for painting. The connection with the tank is made to an extension of the side plates as shown in Fig. 6, plate 6, which shows the form of construction to resist the compressive strains in the sides caused by the water on the conical bottom. The cost of this form of base for different diameters of tanks 50 feet high, is represented by the dotted oblique lines marked "base" on diagram No. 1. Their divergence from the curved lines for the same diameters shows graphically the difference in cost of the base and a continuous stand pipe. The cost is figured at 5 cents per lb. for the base, but I am told by a firm that does a large amount of similar work, that all of the steel in the base can be erected and painted for 4 cents per lb.



Cost of Plain Balconies

20 Ft	Diameter	$165.00
25 "	"	205.00
30 "	"	250.00
35 "	"	285.00
40 "	"	320.00
50 "	"	410.00
60 "	"	500.00
75 "	"	615.00
100 "	"	820.00

Data

Tensile Strength of Material = 50,000 Lbs
Nominal Factor of Safety = 5
Actual " at Joints = 3
Cost of Material Erected = $.05 Lb.

Strain Formula

$$S = \frac{(H\bar{d}).434}{2}$$

$$T = \frac{(H\bar{d}).434}{2(M \times \text{factor})}$$

H = Height in feet
$\bar{d}$ = Diam. " inches
S = Strain in lbs. per vert. inch of metal on each side
M = T.S. of material
T = Thickness of plate in inches

Diagram No. 1

With paper on
Stand Pipes and Their Design
by
Freeman C. Coffin

Explanation

Full curved lines from upper left hand represent Weight and Cost of Sides and Bottom.

Dotted straight lines represent Weight and Cost of Framed Steel Base.

Full straight lines from upper right hand corner represent Capacity in U.S. Gallons.

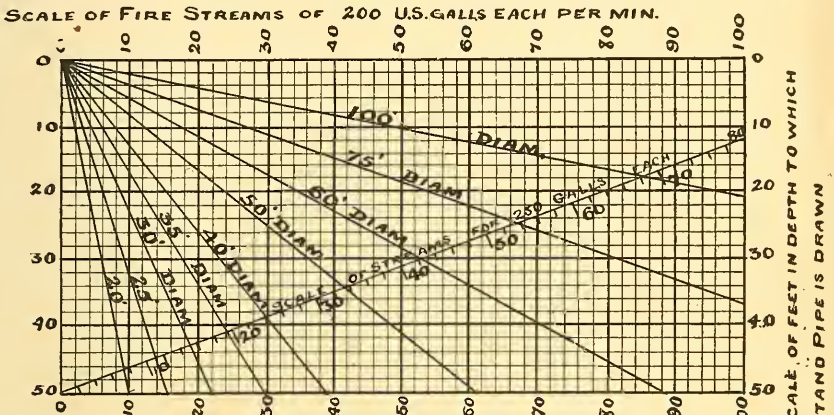


DIAGRAM NO. 3

Showing number of Fire Streams that can be drawn from different depths of Stand Pipes of various diameters per hour

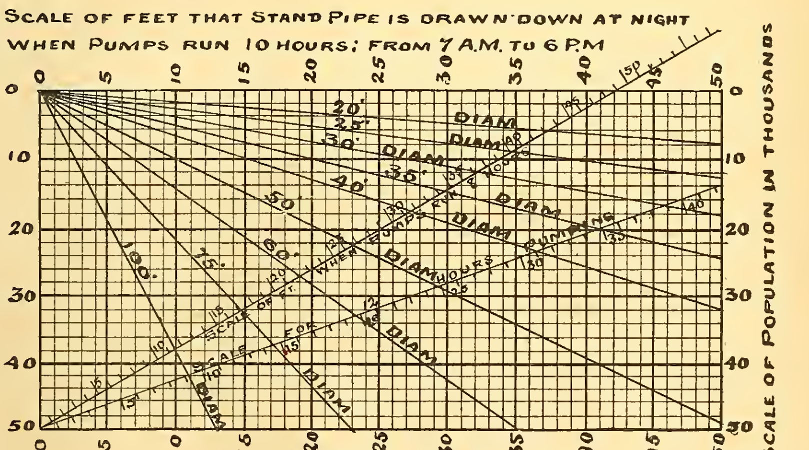


DIAGRAM NO. 2

Showing depths to which Stand Pipes will be drawn by different populations in different intervals of time between pumping

With paper on STAND PIPES AND THEIR DESIGN BY FREEMAN C COFFIN.

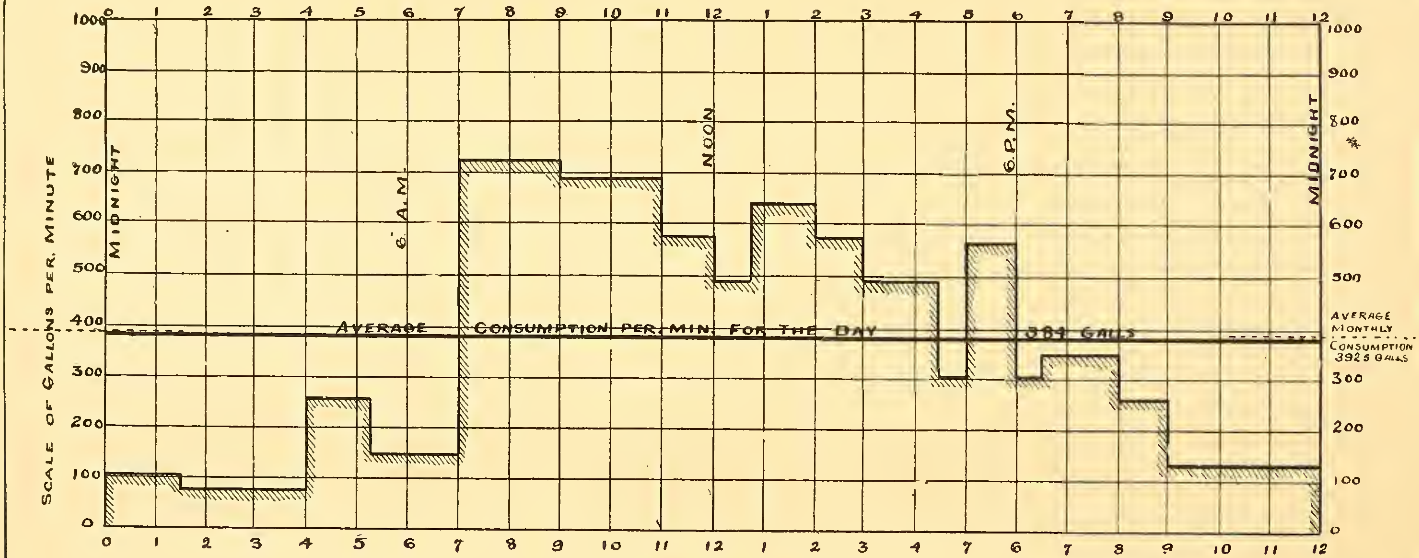


DIAGRAM No. 5

SHOWING CONSUMPTION OF WATER PER. MIN. AT DIFFERENT HOURS OF THE DAY
JUNE 20. 1892

WOONSOCKET R. I.

WITH PAPER ON
STAND PIPES
BY
FREEMAN C COFFIN

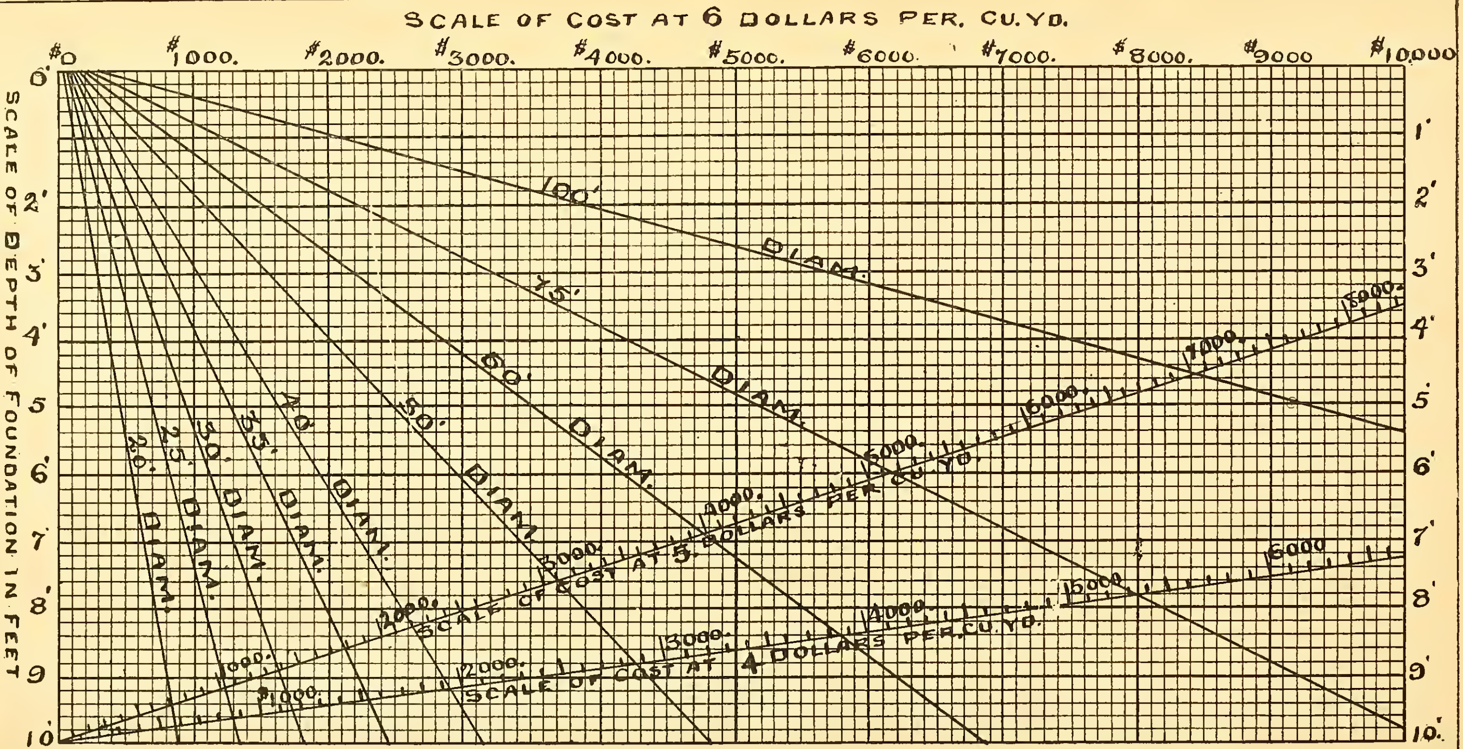


DIAGRAM No. 7

COST OF CEMENT RUBBLE FOUNDATIONS FOR STAND PIPES OF DIFFERENT DIAMETERS

WITH PAPER BY FREEMAN C. COFFIN

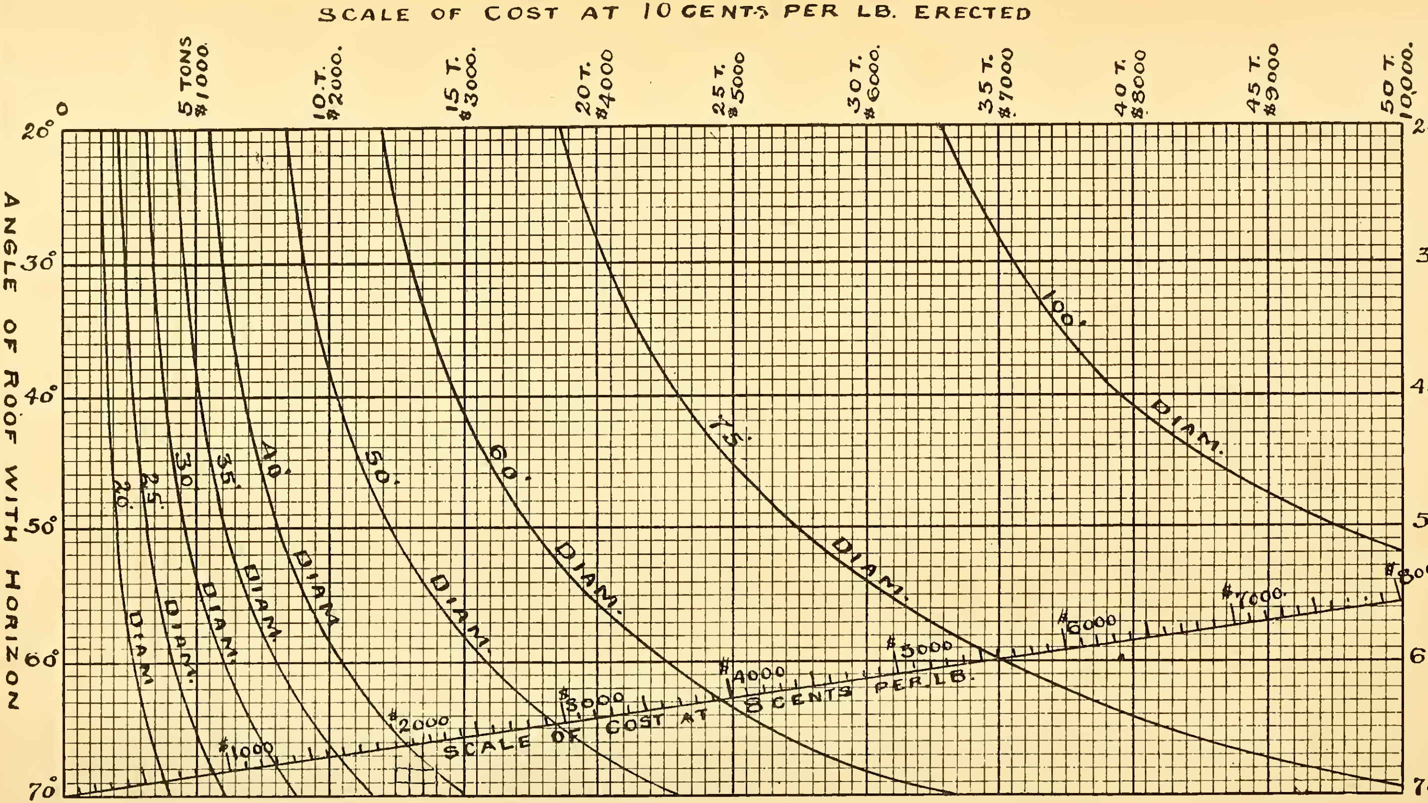


DIAGRAM No. 8

COST OF ROOFS FOR STAND PIPES OF DIFFERENT DIAMETERS

WITH PAPER BY FREEMAN C. COFFIN

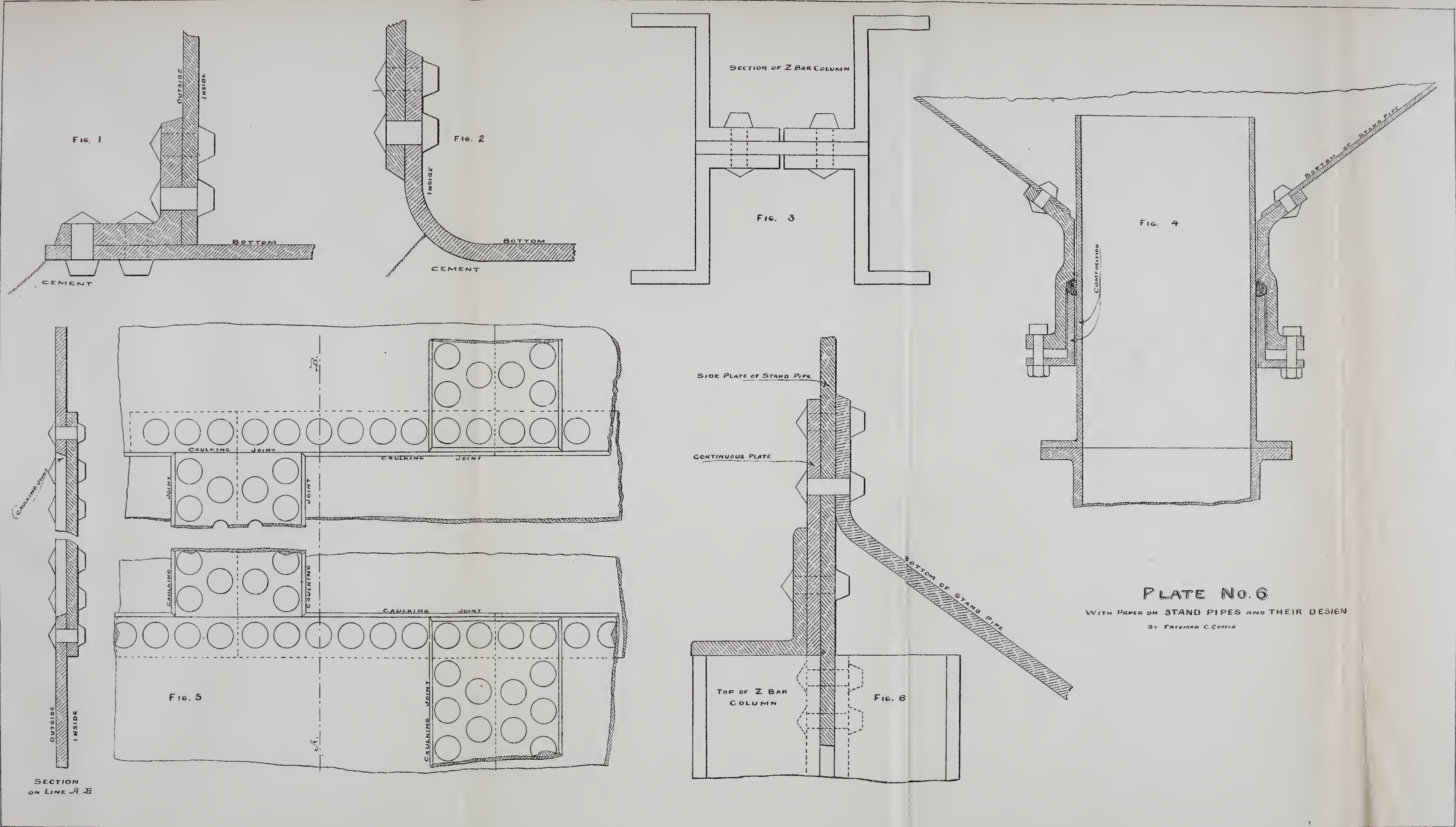
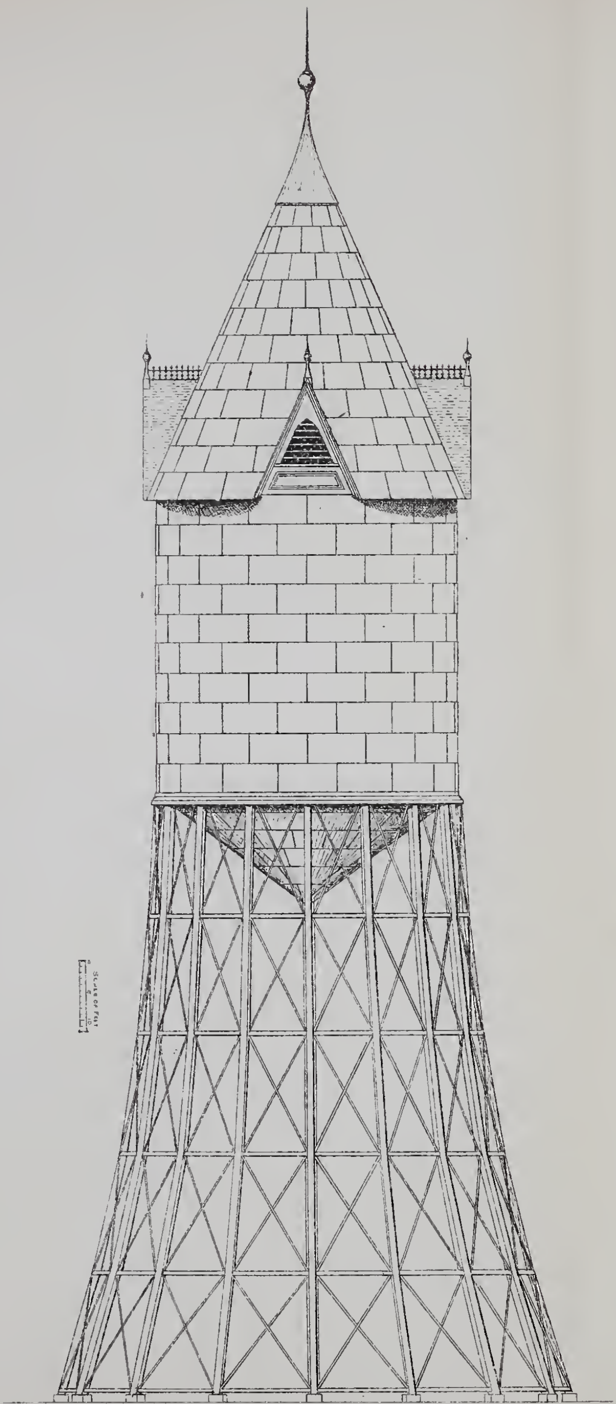


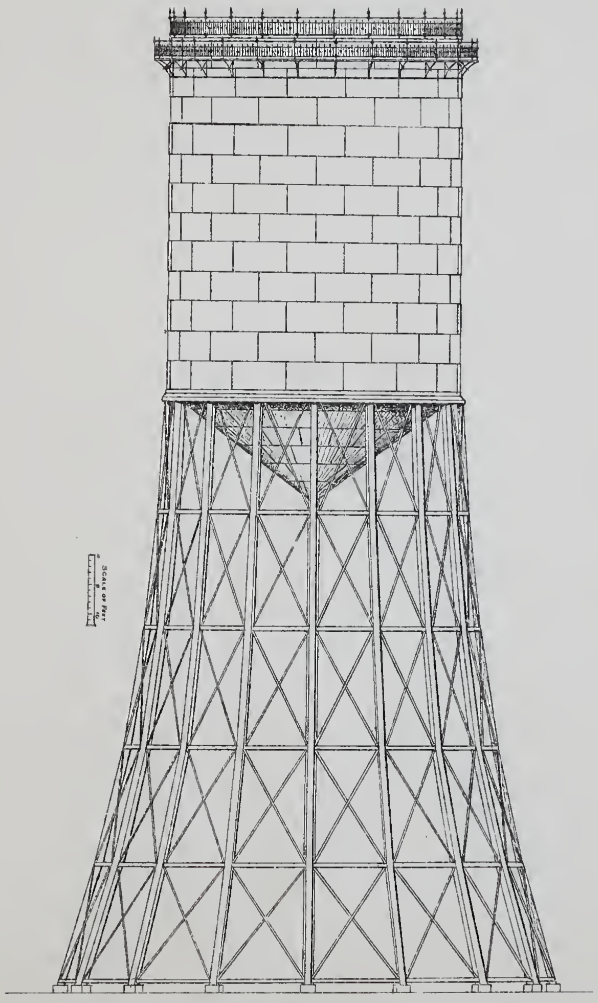
PLATE No. 6

WITH PAPER ON STAND PIPES AND THEIR DESIGN

BY FREEMAN C. COFFIN



ELEVATED TANK 50' DIAM. 50 HIGH FRAMED STEEL BASE 100' HIGH
WITH PAPER ON STAND PIPES AND THEIR DESIGN BY FREEMAN C. COFFIN
PLATE No. 7



ELEVATED TANK 50' DIAM. 50 HIGH FRAMED STFEL BASE 100' HIGH
WITH PAPER ON STAND PIPES AND THEIR DESIGN BY FREEMAN C. COFFIN
PLATE No. 7

A HIGH AND LOW SERVICE STAND PIPE AT ATLANTIC HIGHLANDS, NEW JERSEY.

DESIGNED BY C. P. BASSETT, C. E.

With a Short Description of the Water Supply System.

Contributed to the New England Water Works Association by C. P. BASSETT, Chief Engineer. Prepared and presented by A. P. Folwell, Resident Engineer.

The Water Supply system which it is the intention to describe briefly in this paper is situated at Atlantic Highlands, N. J., a borough on the southwest shore of Sandy Hook bay; and for an adequate understanding of the reasons for some of the features of the design a general knowledge of the location and topography is necessary.

From the northern to the southern limits of New England's coast line mountains and hills extend or send their lesser spurs down to the ocean's very edge; Cape Cod being a notable exception—and even this has a considerable hill at its extreme end. But along the Middle and Southern states the flat monotony of the shore is relieved by very few such picturesque features. The traveler by water coming from the south feels a disappointment in the retiring nature of America's grand scenery; until suddenly there rises into view, above the low lying mists which half conceal the "Hook," a beautiful wood-clad hill—the Highlands of Navesink. No less pleasing than this view from the water is the view of the ocean from this high land, a watch hill which is unique on the coast for the attractions it offers as an observatory and for the beautiful and charming picture of water, smooth and rough, of wooded hills, fertile valleys and prosperous villages which meet the sight on all sides. These highlands are extremely abrupt in both their eastern and western slopes, and it is upon and at the foot of the latter that the town of Atlantic Highlands has been built. The map has been provided with contours taken 5 feet apart, from which it may be seen that in a distance of 1500 feet from the water the ground rises to an elevation of 250 feet above low tide (an average slope of over 16 per cent); and that contours within the borough limits vary by as much as 245 feet A first glance at the town and surrounding country showed the futility of seeking a gravity supply wthin a reasonable distance. There were, moreover, no streams or lakes from which water could be pumped, and the sinking of shallow wells in the neighboring valley was considered; but the water which could be obtained thus was limited in quantity and subject to the objection of possible pollution from population developing upon the contributing water shed. There existed, however, in other New Jersey towns, located over similar geological formation, deep wells furnishing plentiful supplies of water, which suggested that the practicability of an artesian supply be investigated. At Keyport, 8½ miles distant, water

had been found in a sand stratum included between clay marl strata. The state geological survey had found these strata to dip with an incline of from 25 feet to 35 feet per mile. By combining these data, the dip being taken at a mean of 30 feet, it was calculated that water would be reached at a depth of 470 feet in the low-lying western section of the town. Borings were made here and an abundant supply of excellent water found at a depth of 464 feet, in a stratum of sand, and rising 3 feet above the surface. A chemical analysis of this water discovered but one objectionable impurity—iron; which it is proposed to remove by the use of a filter made by the Continental Filter Co.

The highest summit lies at the eastern end of the borough. About 2000 feet west of this is another and lesser one with an elevation of 120 feet above tide water. It would naturally appear, upon a preliminary study of the situation, that these two summits afforded excellent locations for high and low service stand pipes, and this arrangement was considered. There were, however, arguments against this plan and in favor of another which decided the engineer to construct one double stand pipe rather than two separate ones. The lower summit is at the top of an almost circular knoll and is the location of a small private park, all rights in which are held by the owners of the dwellings which entirely surround it. Their consent to the placing of a stand pipe in this park would be given only upon condition that it be an ornamental one provided with an observatory and staircase. And to this the public would be refused access. On the other hand the owners of the land on the eastern and higher summit offered as a gift for the purpose of a stand pipe and reservoir a large lot upon the very summit of the hill, free from all restrictions except that the stucture be ornamental. The high service area to be supplied from this point was small and only a small tank would be required. However the natural and topographical conditions already referred to called for an observatory at this place, and the stipulations of the donors of the land for a more or less ornamental structure. A double expense would thus be called for by two observatories, one of which as such would benefit a very limited number. Should a single stand pipe be built upon the highest land it must of necessity be at least 45 feet high, the water level never falling below 30 feet in order that the high service district be adequately provided for. But, for the low service the head could be reduced several feet—in fact when the increased population warranted it a reservoir would furnish abundant head. It was, moreover, calculated that the cost of the double stand pipe to be described would not greatly exceed that of adding a stairway and observatory to a small high service stand pipe. If it is also kept in mind that but a limited amount of ready money was available, and that anything adding to the attractiveness of Atlantic Highlands to summer visitors would be looked upon in the light of capital, the weight of these arguments is apparent.

For these and other reasons, in place of two separate ones, one double stand pipe upon the higher summit was decided upon and a design made for one to serve both high and low districts, which is believed to be novel and which I will attempt to describe.

Resting upon a suitable concrete foundation, which is brought up to a few inches above the surface of the ground, is the low service stand pipe, directly connected with by far the larger portion of the supply system. This tank is 30 feet in diameter and 35 feet high, having a capacity of 178,000 gallons Resting upon the same foundation and imbedded in the concrete is a hollow cast iron pillar extending vertically through the centre of the low service tank to a height of 30 feet above the foundation. This supports the high service tank, 15 feet in diameter and 15 feet high (having a capacity of 19,800 gallons); the upper 10 feet of it is therefore elevated above the top of the lower tank. Spanning the space between the top of the lower tank and the side of the upper one is a continuous ring of sheet iron, the joints of its plates with each other and with the sides of both tanks being water tight under pressure. In the bottom of this upper tank is a flap valve opening upward. There is an overflow pipe with its funnel mouth a few inches below the top of the upper tank; and a ventilation pipe carried upward from the top plate of the lower tank to a point slightly above the top of the upper one gives free communication with the air and permits the emptying or filling of this tank independently of the other. From the pumps a 10 inch main leads into the lower tank, serving as both inlet and outlet for the low service. Parallel to this for a distance of at least 10 feet from the tank, and connected with it by a 4 inch cross-over is a 4 inch pipe leading up through the hollow cast iron pillar into the upper tank and serving as both inlet and outlet for the high service. Valves are placed in the cross over, and in both the 4 inch and 10 inch mains between it and the stand pipe. After this brief description the working of the tanks can be explained. The details of construction will follow.

Both tanks being empty, the valve in the 10 inch main will be opened and those in the 4 inch main and cross over closed. The pumps being started will then force the water through the 10 inch main into the lower tank. When this has been filled to a depth of slightly more than 30 feet the valve in the bottom of the upper tank will open automatically admitting water into this tank which will in turn be filled to the level of the overflow, when pumping should stop. Meantime the valve in the 4 inch main having been opened, this and the connected service pipes will be filled and both high and low service ready for use.

When the pressure from the pump is lowered the weight of water in the upper tank will close the valve, thus shutting off all connection between the high and low service, as the valve in the cross over has remained closed. It is expected that a short experience in the working of the system will indicate the frequency with which the high service tank must be filled. This will, of course, vary with the increase of population in this district, which from its desirable location, it is expected will soon be completely occupied by the wealthier class of citizens. The area of this high service district is, however, small and it is estimated that even with the fires banked at the pumping station sufficient fire protection will be afforded should the high service tank be kept not less than half full.

When the quantity of water in the upper tank approaches this minimum and it is desired to fill the upper tank before filling the lower, or in case of a fire in the high service district, the valve in the 10 inch main should be closed and that in the cross over opened, when the pump will force directly into the high service main and tank. By closing the valves before referred to in either the 10 inch or 4 inch main either tank can be cut off from the system and cleaned or repaired.

A firm natural foundation of compact sand and gravel is found at the site of the stand pipe. The artificial foundation consists of concrete thoroughly rammed in layers of 6 inches, 36 feet in diameter and 4 feet deep, 3 feet 6 inches being below and 6 inches above the surface. Concrete is thoroughly packed around the inlet, outlet and overflow pipes, and placed to a depth of $5\frac{1}{2}$ feet where the pipes occur and 6 inches wider than the external diameter of the flanges or hubs of the pipes. That part of the foundation under the bed plate of the central column is of portland cement concrete. The concrete is composed of one, two and three parts of cement, sand and broken stone respectively.

The lower stand pipe has six plates in circumference; the upper one, three. The first two plates of the lower stand pipe are 9-16 inches thick, the next two 7-16 inches thick, the next three 5-16 inches thich. The bottom is $\frac{3}{8}$ inches thick and the top plate of the bottom stand pipe is $\frac{3}{8}$ inches thick supported on angles and braces as shown on the plans.

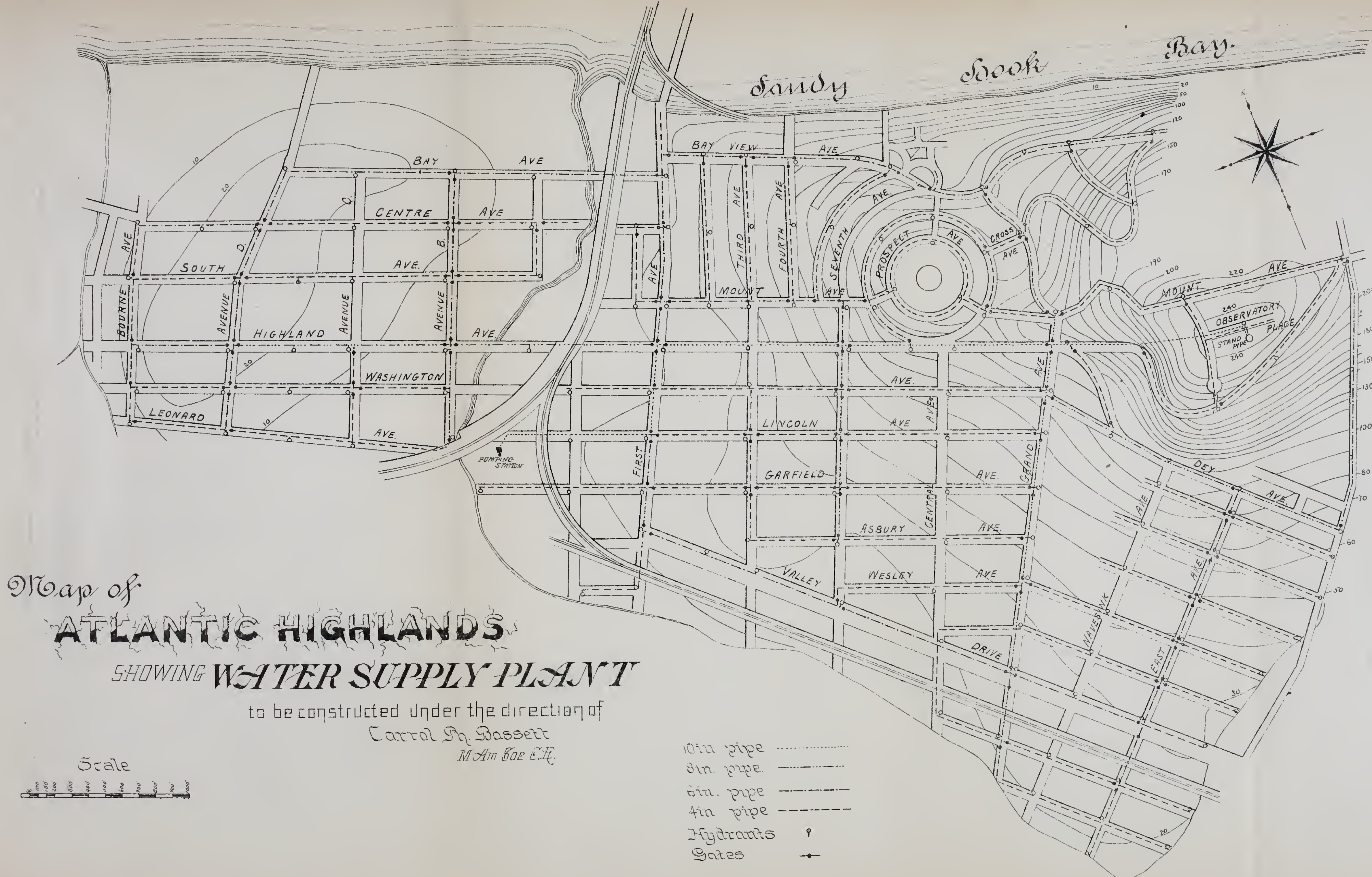
All horizontal seams are single riveted, lap joints; all vertical seams are double riveted, lap joints.

A manhole, 18 inches $\times$ 24 inches, is built in a lower sheet of the bottom stand pipe.

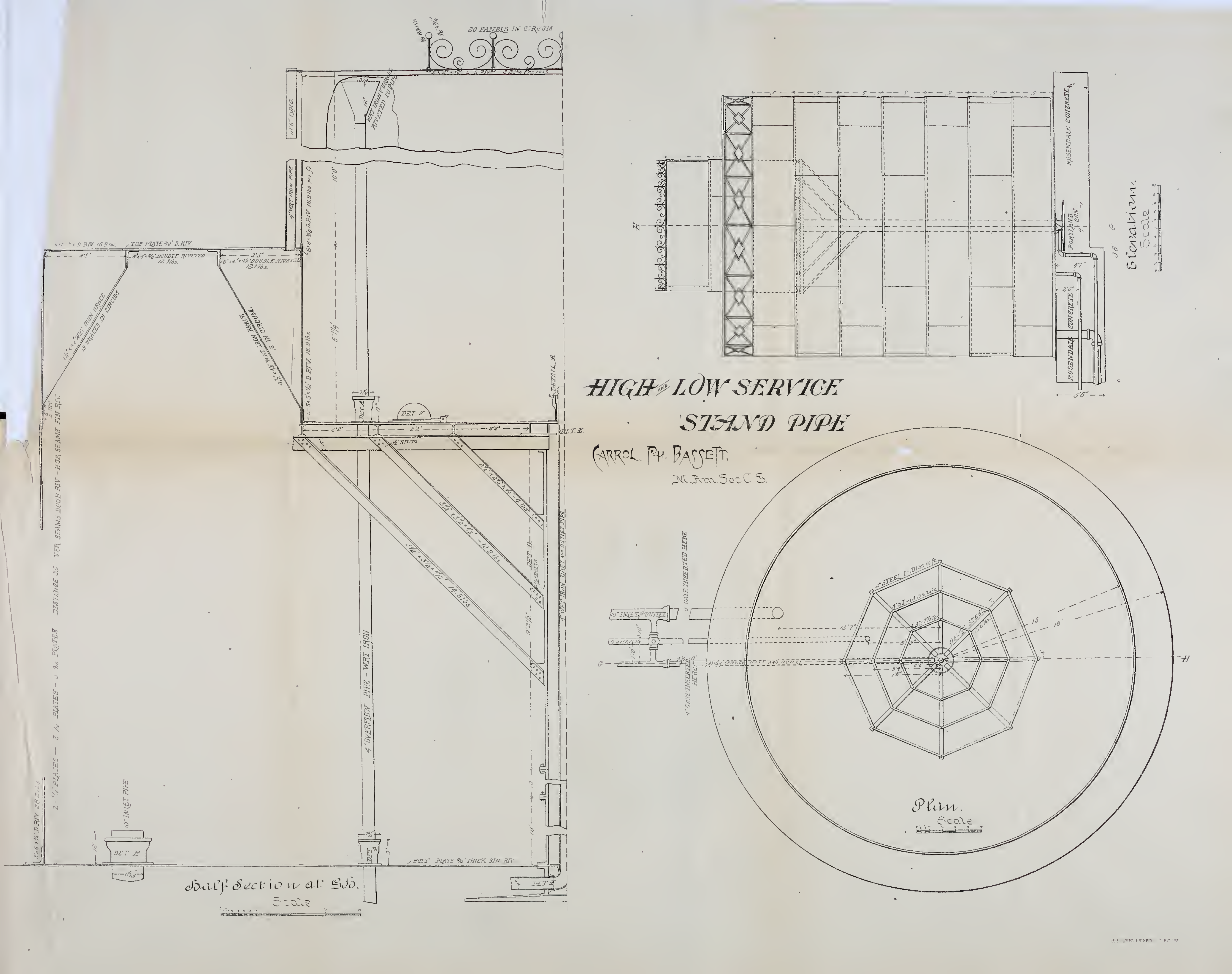
All wrought iron is tough, fibrous and of uniform quality; that for plates and angles showing a minimum ultimate tensile strength of 48,000 pounds per square inch.

Supporting the top plate of the lower stand pipe, which acts as the floor of the observatory, are two sets of braces inside the tank, numbering 34 in all. A railing above the sides of this stand pipe surrounds the observatory, standing $3\frac{1}{2}$ feet above the floor.

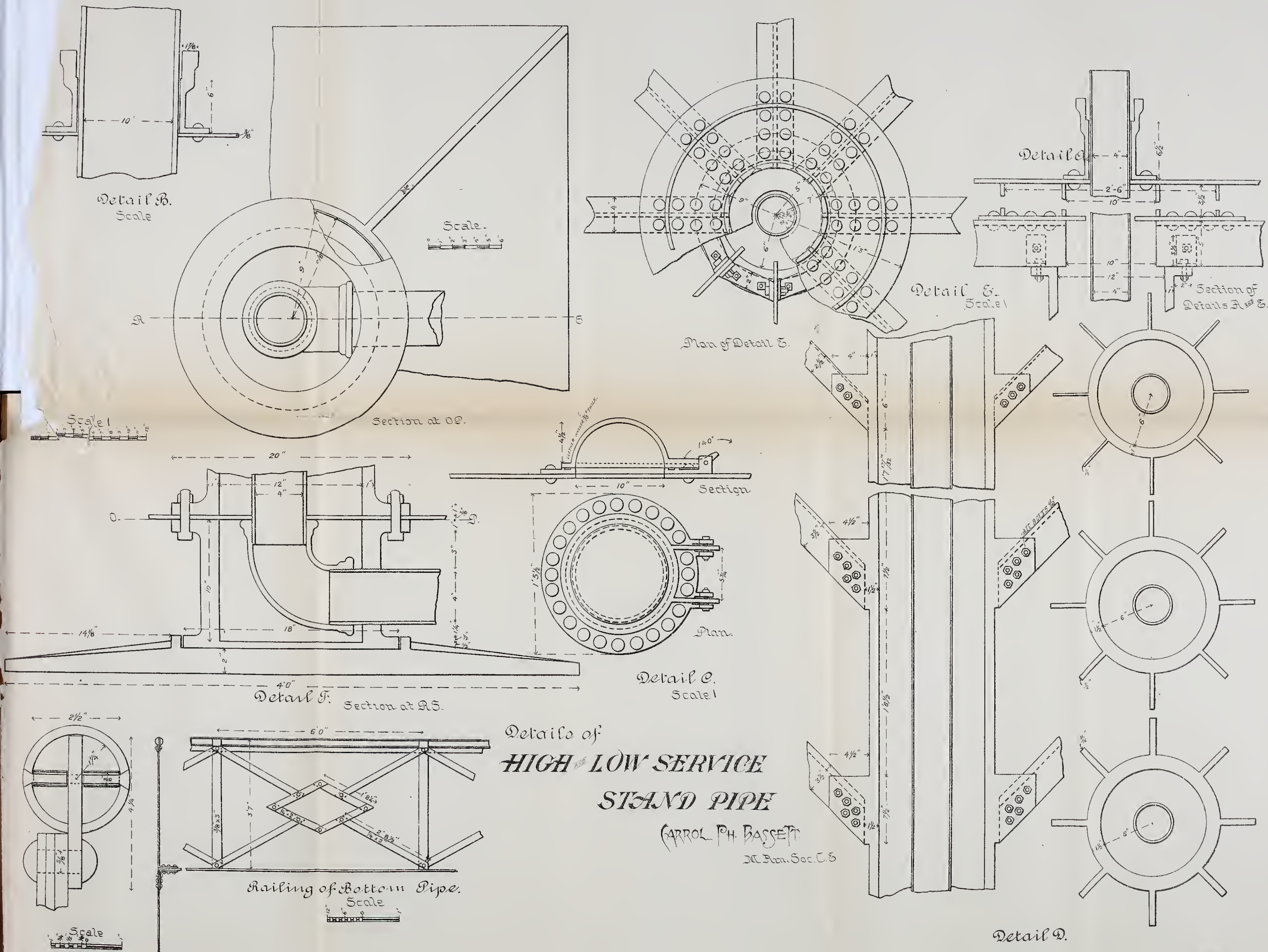
One foot below the top surface of the foundation, in the centre of the stand pipe, is set a cast iron foot plate 4 feet square, which sustains the weight of the upper tank. The load upon the concrete transmitted by this foot plate when the upper tank is full would therefore be about 80 pounds per square inch. Bolted to and resting upon this foot plate is a hollow cast iron pillar, 1 foot interior diameter and 1 inch thick, rising vertically to a height of about 30 feet above the foundation. Cast on this are three rows of lugs, eight lugs in each row around the pillar, to which are riveted 24 angle iron braces serving to support the beams upon which the top tank rests. These beams are 5 inch steel tees, eight in number, radiating from the cast iron pillar upon which they rest, and connected by a circular wrought iron plate to which they are riveted. Resting upon these beams and forming the im-



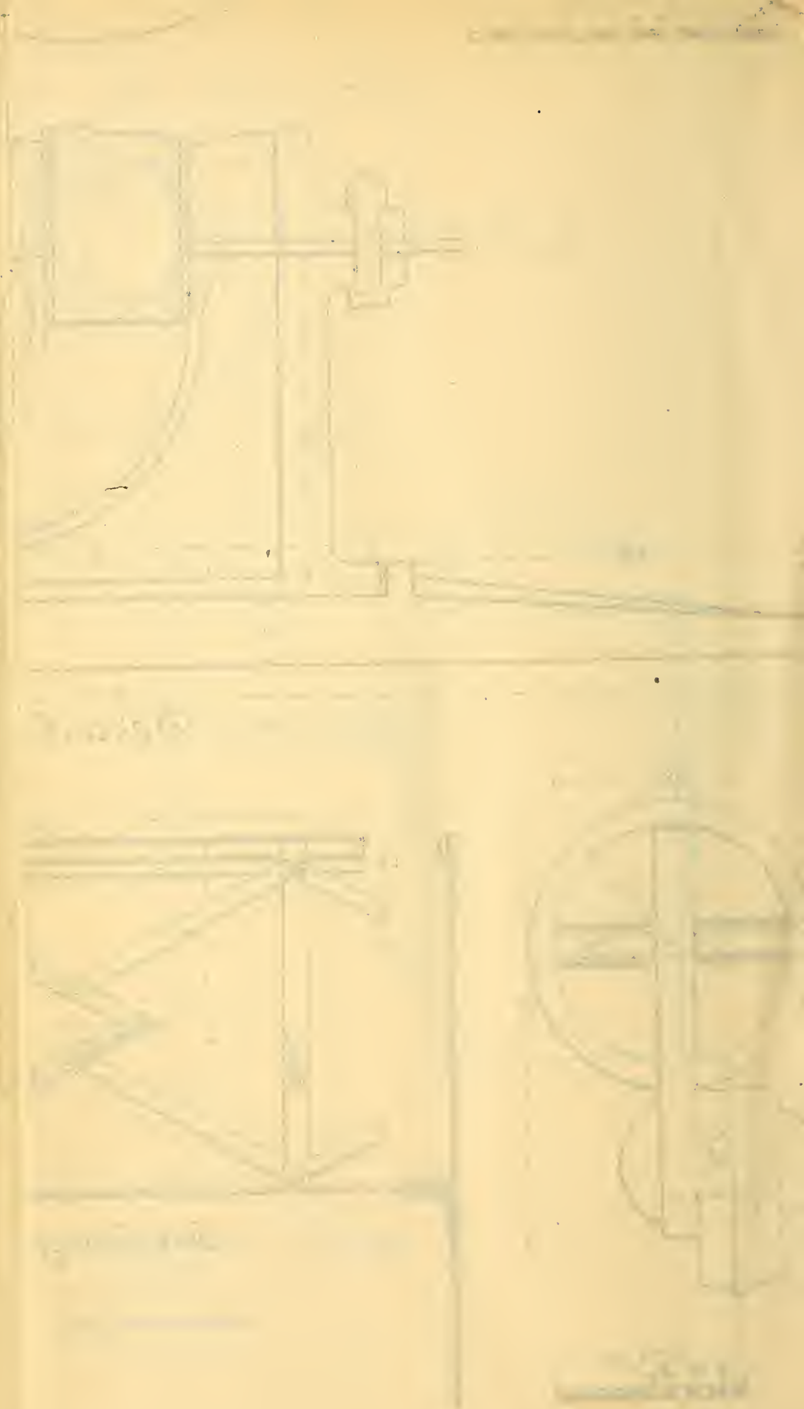
HELIOTYPE PRINTING Cº. BOSTON



HIGH AND LOW SERVICE
STAND PIPE
CARROL PH. BASSETT.
M. Am. Soc. C. E.
Elevation.
Scale
Plan.
Scale
Half Section at GH.
Scale
20 PANELS IN CIRCUM.
4" OVERFLOW PIPE - WRT IRON
10" INLET PIPE
ROSENDALE CONCRETE
PORTLAND CON.
BOTT. PLATE 5/8" THICK SIN. RIV.



Detail B.
Scale
Scale.
Section at O.P.
Plan of Detail E.
Detail E.
Scale 1
Detail C.
Section of Details A and E.
Section
Plan.
Detail C.
Scale 1
Detail F.
Section at R.S.
Details of
HIGH AND LOW SERVICE
STAND PIPE
CARROL PH. BASSETT
M. Am. Soc. C.E.
Railing of Bottom Pipe.
Scale
Scale
Detail D.



mediate support for the upper tank are 4 inch steel I beams spanning the spaces between the T beams and arranged as chords of three concentric circles. The upper tank has a bottom of $\frac{1}{2}$ inch and sides of $\frac{1}{4}$ inch iron, is 15 feet high and surrounded by wrought iron fret-work. Riveted to the bottom is a flap valve acting upward, the circular orifice having a diameter of 10 inches. A 4 inch overflow pipe which leads to the sewer extends through the bottoms of both tanks, and is topped by a funnel whose mouth is $13\frac{1}{2}$ inches in diameter and 6 inches below the top of the upper tank. Where this and all other pipes pierce the bottom of either tank a water tight connection is made by means of a cast iron flange surrounding the pipe, riveted to the bottom plate and caulked with lead around the pipe.

The 4 inch inlet pipe for the upper tank is laid through the concrete foundation and rises inside the cast iron pillar to a distance of a foot above the bottom of the tank. This serves also as the outlet pipe. A 4 inch pipe pierces the top plate of the lower tank and rises to a few inches above the top of the upper tank. This allows for escape and admission of air as the water rises or falls in the lower tank.

The 10 inch pumping main, rising a foot above the bottom of the lower tank also serves as both inlet and outlet pipe.

As the stand pipe is placed at one side of the borough, while the pump is near the centre; and as the pumping main also serves as a distribution main, this is practically a direct pumping system; the stand pipe, in its character as a reservoir, acting mainly as a reserve for fire and other emergencies, and for supplying the slight night consumption, when the pumps will be idle. With this condition in view the pumps are made with long stroke and consequent low speed, the latter being at a rate of 60 feet per minute. The entire lift of the pumps from the wells to the top of the stand pipe is 300 feet. Calculation is made on a basis of a present daily consumption of 750,000 gallons; but provision is made for duplicating the pumping plant in the future.

An area of ground adjacent to the stand pipe is held sufficient for a reservoir should this at some time be needed; in which case the pumping main would lead directly into the reservoir, and a branch from this main connect with the stand pipe. The necessity for this additional storage may be created by future extension of population into districts south and east of the stand pipe which are outside the present borough limits.

LAYING A MAIN ON A RIVER BOTTOM. THAWING FROZEN SERVICE PIPES. PLUGS.

An Experience Talk.

BY

Chas. K. Walker, Superintendent, Manchester, N. H.

In laying an 8 inch main across the Merrimac river I adopted, by the advice of a contractor and contrary to better judgment, a pipe $\frac{3}{4}$ inch thick with a bell 3 inches deep, but it proved an utter failure, breaking in two the first winter and pulling apart the next year. As a substitute an 8 inch main was laid across the bridge and left exposed, and it stands today all right. My experience is this: If I was to lay a pipe across the river in the same place today, I would get one an inch thick and have the joints similar to those used in Boston. I would have a 5 inch bell, and three set screws to each joint. I wouldn't connect it on either side until it had settled a week or two, and I would drive those joints and run the lead beyond the set screws, and I wouldn't be afraid to drop that pipe anywhere in any river or on any kind of bottom.

We have had a little experience in thawing out service pipes. We have tried various ways, and now we dig a hole two feet deep and about three feet across, we put in some lime and pour on some water, go home and go to bed, and the next morning everything is all thawed out.

Now, plugs. Did you ever have any trouble with plugs? They are about ten times as heavy as they ought to be, and when you come to break them out you can't do it without much trouble. I have had lighter ones made, about half or three-quarters of an inch thick that worked all right. But the best plug is the old plug they take out of cement pipe, and that is all there is good about a cement pipe, the plug.

THE LIFE OF SERVICE PIPES.

An Experience Talk.

BY

Mr. F. L. Fuller, Civil Engineer, Boston.

The Wellesley Water Works were built in 1884, service pipes were put in during the fall, the next spring and summer, and the kind of pipe adopted was plain tarred pipe. It was necessary to hurry to get them in, especially in the fall, and that seemed to be the most available pipe, so the services were put in of tarred iron pipe without any lining. During the past year we have added a good many meters to the system, and some of those pipes have been cut. In 1886 or 1887 we changed from the iron pipe to the cement lined pipe, and what I wish to present to you today is the condition of some of those first service pipes which were put in. I have a few samples here, and perhaps you may be interested to see them. Most of them have been in from six to seven years, and by looking at them you can see what sort of a condition they are in. (The speaker exhibited samples of several kinds of pipe.)

I had some curiosity in my own house to know about what the flow would be through an ordinary service pipe, and so I put 50 feet of rubber hose on to a faucet at my sink, and carefully measured the flow of that water. This service pipe was put in in the spring of 1886, and in November of that year I measured the flow through that pipe. I put on this piece of hose and carefully measured a wash tub and saw how long it took to fill this wash tub under those conditions, and the time, as I recall it was one minute and five seconds. I thought this last winter I would repeat the same operation, and with exactly the same piece of hose and the same wash tub. I found the time required was seven minutes and fifty seconds; so you can judge what the condition of the service must have been, the time varying from one minute and five seconds in 1886 to seven minutes and fifty seconds in 1893. The flow in the first instance was about 15 gallons a minute, or a little over; this year it was two gallons a minute.

Mr. FitzGerald. The same pressure on the main?

Mr. Fuller. Just the same conditions exactly. The pressure at that point is somewhere in the neighborhood of 70 pounds. It seems to me any town is very foolish to put in either plain pipe or tarred pipe. It is much better to put in cement lined pipe, or possibly the lead lined pipe, although we haven't had any experience with that. But this experiment of measuring the flow of that pipe after such an interval of time convinces me that plain iron pipe is not a proper pipe to put in for services.

LOCATION OF BROKEN MAINS AND EXAMINATION OF HYDRANTS IN COLD WEATHER.

An Experience Talk.

BY

George A. Stacy, Superintendent, Marlboro, Mass.

Mr. President, what little I have to say today will give you my experience in the discovery of a break in a 16 inch main when there was about three feet of frost in the ground. We had just laid this main, and it had been under pressure about three weeks when word came that there was something the matter with the pumps and I was wanted up there immediately. I drove up expecting to find that something had broken. About 500 feet from the station, in a slight depression in the street, I saw quite a lake of water. We shut off the small district which was supplied by this force main, and then waited until the water subsided in the street, when we expected to find an upheaval in the ground large enough to indicate where the break had occurred; but to our surprise we couldn't find any place where the ground wasn't as hard as before. After a little investigation we found that the water had come up from a culvert, which crosses the road at the lowest point in the depression. It was evident that the water had forced its way from the break through the ground into this culvert in such a volume that it could not discharge into the lake which was immediately on the other side, and so had come up out of the culvert, which was about eight inches deep, and had filled the road. Now, the question was, where was the break? We could not tell which side of the culvert it was, and as there was three feet of solid frost in the ground, how were we going to find the break without digging the whole length ? We couldn't get into the culvert to see which way the water was running, and we didn't want to go to work blindly, for the break might be 100 feet either side of the culvert, or it might be close to it.

The method I adopted to locate the break was as follows : With a common stone drill, we drilled through the frost at one point and found practically dry earth under the frost there; then we went up beyond the culvert about 100 feet and found practically dry earth under the frost there; so I was satisfied the break was somewhere between those two points. At the fourth drilling, as soon as the drill went through the frost it dropped, and we found plenty of water, and when we dug down I found we were within two feet of the fracture. This is perhaps a small matter to speak about, but I thought I could mention it here, for possibly my experience might save somebody some trouble in the future if he should happen to find himself in a like situation. It saved me a great deal of labor, and I found it very easy to locate the leak

in this way. I might add that the break was from 25 to 30 feet to the west of the culvert. I found by drilling these holes that the water had washed out the dirt as it flowed towards the culvert so it told you very readily whether you were nearing the break, and by dividing up the distance it didn't take a great while to come close to the point, and we struck within two feet of it when we drilled the last hole. We then went immediately to work and made the repairs.

During the severe weather this winter we have had good fortune in Marlboro in regard to our hydrants. I know some people advocate the inspection of hydrants in the fall and not touching them again during the winter except in case of fire. But I don't see how it is possible to follow that plan with any certainty of safety. I know the theory is that if a hydrant is all right in the fall and then is not disturbed, it will remain all right, but I do not find it so in my experience. During the past winter we have found four hydrants out of 281 frozen, and one case occurred about a month ago, a hydrant that has been set ever since 1883 and had naver before given us trouble. We knew it was properly drained, the drip was clear, and it always had worked free. It had been examined every 48 hours in cold weather, and every 24 hours in extreme cold weather, as we examine every hydrant in the city, but yet one morning about 8 o'clock one of my men found it stuck. We went up there with the pump and thawed it out, finding the ice was within a foot or six inches of the surface of the street. It was quite a mystery for a while how the water had got in there. The hydrant was set near an embankment where the natural slope of the ground water was away from it, it is set extra deep, and we never had had any trouble whatever with it. The mystery was explained two days afterwards by finding a leak in a service pipe which tapped the main within two feet of the hydrant branch. The water had forced its way along the pipe, the frost being so deep it could not come up through the ground, and consequently it put pressure enough in the ground to fill the hydrant post up within a foot or six inches of the surface. Now, no man could tell whether that hydrant was frozen or not unless he examined it. It was all right in the fall, it is all right today, and it was all right the minute that leak was repaired. This is why I say no man can feel safe about his hydrants if he does not examine them frequently in cold weather; and this experience shows the danger even under a system of inspection, for this hydrant had been examined certainly within 48 hours, and was found to be all right. I had another experience where the water followed a service pipe down through a ledge which was blasted out to set the hydrant and where we had run the pipe up through the hydrant trench to avoid extra blasting, it followed down through there and got into the hydrant post and froze. These little things are occurring all the time, and so "eternal vigilance" is necessary during cold weather, and even then, when you are trying to do your very best, you are liable to get caught and get blamed for it. It may do in some places, but certainly it won't do for me to sit down and say the hydrants are all right in the fall, and therefore they are going to remain so without further attention until spring, unless there is a fire.

The President. I suppose Mr. Stacy doesn't make such an examination as some of the firemen would like to make, by putting on a hose and opening the valve.

Mr. Stacy. If the hydrant is all right I don't believe, of course, in disturbing it. I believe hydrants should be made so they can be tested without disturbing them. I can test my hydrants as fast as I can walk along the street and be absolutely sure they are all right, for the reason that if the supply pipe is not frozen, the water in the bottom of the hydrant will not be frozen, and the spindle will be free. If the water in the supply pipe is frozen it will grip the spindle and hold it as rigidly as in a vise. The back lash in the nut of the valve permits the movement of the spindle to a slight extent, and by that method we can determine whether the hydrant is free or not.

STATISTICS

FOR

The Years 1888—1892.

IN FORM ADOPTED BY THE

New England Water Works

ASSOCIATION.

Table I—General and Pumping.

Table II—Financial.

Table III—Consumption.

Table IV—Distribution—Main Pipe.

Table V—Distribution—Service Pipe.

Compiled by
Senior Editor,
Boston, Mass.

TABLE I.—GENERAL AND PUMPING.

Statistics for the Years 1888–1892. In Form Adopted by the New England Water Works Association.

Compiled by the Senior Editor.

Name of Place.	Year.	Date of Construction.	By whom owned.	Source of Supply.	Mode of Supply.	1. Builders of Pumping Machinery.	2. Coal Used.	2. Per cent ashes.	2. Price per ton of 2,240 lbs.	3. Coal consumed for year, lbs.	4. Lbs. of Wood.	5. Total fuel consumed for year, lbs.	6. Total pumpage for the year in gallons.	7. Average static head against pumps.	8. Average dynamic head against pumps.	9. No. of gallons pumped per lb. of coal.	10. Duty in ft., lbs. per 100 lbs. coal, no deductions.	11. Cost per million gallons pumped into reservoir. Fig'd on pumping station expenses.	12. Cost per million gallons raised 1 ft. high. Figured on pumping station expenses.	13. Cost per million gallons pumped into reservoir. Figured on total maintenance.	14. Cost per million gallons raised 1 ft. high. Figured on total maintenance.
Boston (Cochituate Works)	1888	1848	City	Lake Cochituate and Sudbury River.	Gravity and pumping to Reservoir	Holly Man. Co.	Bituminous	7.3	$ 4.98	2,626,558		2,626,558	1,805,374,800		126.4	687.	72,459,200	$ 8.69	$ 0.069	$	
"	1889	"	"				"	7.9	4.78	2,462,750		2,462,750	2,143,925,800		123.2	870.5	95,445,400	7.86	0.064		
"	1890	"	"				"	8.2	4.70	2,677,281		2,677,281	2,369,631,700		123.2	885.	98,069,200	7.61	0.062		
"	1891	"	"				"	8.5	4.90	2,910,751		2,910,751	2,651,164,400		124.6	911.	101,380,800	6.65	0.053		
"	1892	"	"				"	8.5	4.66	3,518,105		3,548,105	3,050,018,300		126.3	941.	99,195,300	6.15	0.049		
Boston (Mystic Works)	1888	1864	"	Mystic Lake	Pumping to Reservoir	H. R. Worthington	Bituminous	8.4	4.23, 4.29	6,924,000		6,924,000	3,022,322,400		147.62	436.	53,750,600	8.07	0.055		
"	1889	"	"	"			"	8.0	4.88	6,286,000		6,286,000	2,857,969,490		146.5	455	55,554,200	8.89	0.061		
"	1890	"	"	"			"	9.8	4.20	6,506,000		6,506,000	3,030,116,500		147.1	465.	57,141,800	7.76	0.053		
"	1891	"	"	"			"	10.2	4.34	6,988,500		6,988,500	3,304,951,000		148.	473	58,380,500	7.85	0.053		
"	1892	"	"	"			"	10.2	4.13	7,873,000		7,873,000	3,596,716,400		148.8	457.	56,709,000	7.09	0.048		
Burlington	1888	1867–68	City	Lake Champlain	Pumping to Reservoir	H. R Worthington	Anthracite and Mill Shavings		4.65				254,360,275	289.	316.			21.58	0.068	98.11	0.31
"	1889	"	"	"					4.75				257,558,200	289.	316.			24.57	0.078	103.49	0.33
"	1890	"	"	"			"		4.85				279,371,350	289.	316			21.52	0.068	98.83	0.312
"	1891	"	"	"			"		4.85				298,500,575	289.	316			23.13	0.073	104.92	0.332
"	1892	"	"	"									288,090,575								
Fall River	1888	1874	"	Watuppa Lake	Pumping to Stand Pipe and Tank	Botson Machine Co., H. R Worthington, Davidson Steam Pump Co.	Bituminous	9.6		2,022,935		2,022,935	647,279,612		185.5	320.		10.70		185.74	
"	1889	"	"	"			"	8.5		2,051,920		2,051,920	685,447,036		184.9	334.		12.47		178.50	
"	1890	"	"	"			"	8.4		2,339,435		2,339,435	779,706,398		184.9	333		12.07		157.75	
"	1891	"	"	"			"	7.6		2,637,333		2,637,333	859,830,568		185.9	326.		12.19			
"	1892	"	"	"			"	7.3		2,588,420		2,588,420	836,656,878		187.0	323.		11.77		153.18	
Fitchburg		1871–72	City	Storage Reservoirs.	Gravitation																
Holyoke		1873	"	Two lakes and two streams	Gravitation																
Lynn	1888	1870–72	"	Four artificial storage basins.	Pumping to Reservoir	Engine designed by E. D. Leavitt, Jr., built by I. P. Morris, Deane Steam Pump Co., and Loretz Engine Co.	Bituminous		5.49	1,398,105		1,398,105	906,397,617		168.6	641.1	101,831,525	9.12	0.054		
"	1889	"	"				"		5.54	1,295,522		1,295,522	895,966,403		170.2	691.6	106,628,900	8.65	0.05		
"	1890	"	"				"		5.32	1,236,165		1,236,165	967,336,364		172.4	782.	116,930,878	7.65	0.014		
"	1891	"	"				"														
"	1892	"	"				"	5.4	4.98	1,739,483			1,299,041,098		158.8	760.4	100,789,536	7.49	0.047	75.45	0.47
New Bedford	1888	1866–69	City	Acushnet River	Pumping to Reservoir	Quintard Iron Works		11.9	5.48	812,135	631	812,769	471,008,048	125.7	136.1	580.	65,764,214				
						H. R. Worthington.	Anthracite	10.2	5.89	494,912	267	495,179	227,035,848	125.	128.5	459.	49,123,434	8.83	0.067	62.94	0.48
						H. R. Worthington.				820,193	266	820,459	533,954,736	125.3	127.4	651.	70,340,235				
"	1889	"	"	"		Quintard Iron Works.				736,914	367	737,281	446,583,568	125.7	135.0	606.	68,202,718				
						H R. Worthington.	Anthracite	10.2	5.89	154,700		154,700	74,535,760	124.9	126.2	482.	50,709,050	8.04	0.062	56.59	0.435
						H. R. Worthington.		9.6	5.44	1,138,515	300	1,138,815	777,506,410	125.3	127.6	683.	72,689,510				
"	1890	"	"	"		Quintard Iron Works.				1,242,730	585	1,243,315	755,911,579	125.2	134.5	608	68,199,024				
						H. R. Worthington.	Anthracite	9.6	5.44	220,935	405	221,340	109,852,408	124.8	126.0	497.	52,166,255	7.12	0.054	50.31	0.384
						H. R. Worthington		13.2	4.50	792,350	270	792,620	597,191,364	125.	127.4	754.	80,022,754				
"	1891	"	"	"		Quintard Iron Works				1,271,900	650	1,272,550	774,010,775	125.6	134.9	609.	68,410,278				
						H. R. Worthington.	Anthracite	13.2	4.50	191,000	67	191,067	91,483,092	124.7	126.0	479.	50,298,363	6.99	0.053	62.19	0.474
						H. R. Worthington.		13.0	5.15	918,679	333	918,697	659,290,958	125.3	127.6	718.	76,375,766				
"	1892	"	"	"		Quintard Iron Works	Anthracite	13.0	5.15	934,150	200	934,350	584,860,523	125.8	135.1	626.	70,523,414				
						H. R. Worthington.		13.2	5.00	428,100	267	428,367	214,567,440	125.1	126.3	501.	52,757,332	6.90	0.053	48.23	0.37
						H. R. Worthington.	Bituminous		4.00	1,095,680	267	1,095,947	792,588,940	125.6	127.9	723.	77,160,824				
New London		1872	City	Lake Konomoc	Gravity																
Newton	1888	1876	"	Filter Basin near Charles River.	Pumping to Reservoir	H R. Worthiogton	Bituminous		5.10	1,024,600	21,952	1,046,552	256,031,474	176.1	230.1	274.	52,560,574	23.20	0.10	287.23	1.25
"	1889	"	"				"		5.25	1,289,600	19,200	1,308,800	315,370,007	176.8	227.7	241.	45,758,964	16.85	0.07	243.40	1.07
"	1890	"	"				"	6.0	4.87	1,310,900	12,800	1,353,700	359,487,217	176.6		266.		18.85		227.10	
"	1891	"	"				"	6.0	4.90	1,542,700	13,000	1,555,700	388,753,278	199.6		252.		13.83		226.71	
"	1892	"	"				"	6.0	4.63	1,410,200	13,000	1,423,200	463,686,000	235.	235.	325.	63,854,000	13.39	0.057	203.56	0.866
Plymouth	1888	1855	Town	Great and Little South Ponds and Lout Pond.	Low service Gravity. High service pump to Reservoir.	H. R. Worthington	Bituminous														
"	1889	"	"				"		4.90	196,275		196,275	94,992,542	64.	66.	485.	26,675,000	12.59	0.189	110.07	1.67
"	1890	"	"				"		4.89	199,055		199,055	94,721,616	65.	66.	476.	26,695,000	17.13	0.233	112.44	1.73
"	1891	"	"				"		4.95	209,460		209,460	100,124,640	65.	66.	478.	26,311,582	17.88	0.27	104.70	1.58
"	1892	"	"				"		4.80	219,250		219,250	99,863,280	65	66.	455.	25,070,890	19.83	0.30	113.47	1.72
Springfield		1864–90	City	Storage Reservoir.	Gravity																
Taunton	1888	1876	"	Ground water and Taunton River.	Direct Pumping	Holly Man. Co.	Anthracite	13.0	5.58	812,000		812,000	275,188,656		153.	339.	43,244,609	19.45	0.126	146.41	0.96
"	1889	"	"				"	13.0	5.27	817,882		817,882	280,885,963		152.2	343.	43,381,403	12.09	0.079	138.99	0.91
"	1890	"	"				"		5.15	819,400		819,400	290,801,368		152.4	355.	45,107,785	18.68	0.122	138.13	0.90
"	1891	"	"				Ant. & Bit'ms		5.15, 4.60	929,100		929,100	374,107,200		152.5	403.	50,972,800	15.03	0.098	112.58	0.74
"	1892	"	"				Bituminous	13.0	4.35	910,600		910,600	370,453,491		152.8	407.	51,843,636	14.77	0.097	119.39	0.78
Troy	1888	1833	City	Five Storage Reservoirs in valley of the Piscawankill River, also the Hudson River.	Gravity and Pumping	Holly Man. Co.	Anthracite		2.57, 2.43, 2.37	4,578,604											
							Bituminous	18.5	3.6, 4.2, 3.42	2,428,227	250	7,006,833	1,741,866,964	231.	242.	252.	51,082,700	13.82	0.06		
"	1889	"	"				Anthracite		2.37, 2.21	4,609,808											
							Bituminous	17.9	3.42, 3.31	2,117,928	193	6,727,736	1,736,863,103	231.	242.	254.	51,471,826	12.07	0.052		
"	1890	"	"				Anthracite		2.21, 2.11	3,560,517											
							Bituminous	19.7	3.31, 3.25	1,617,571	2,033	5,180,121	1,306,773,232	231.	242.	252.	50,934,520	14.37	0.062		
"	1891	"	"				Anthracite		2.11, 2.01	5,236,387											
							Bituminous	18.3	3.25, 3.20	2,657,550	2,033	7,893,937	2,006,391,914	231.	242	254.	51,298,366	11.60	0.050		
"	1892	"	"				Anthracite		2.01	8,069,652											
							Bituminous	18.0	3.20, 3.80	1,018,571		9,088,223	2,210,887,684	231.	242.	245.	49,098,601	11.75	0.051		
Waltham	1888	1872–73	City	Filter Basin near Charles River.	Pumping to Reservoir.	H. R. Worthington.	Anthracite	12.7	6.68	713,900		713,900	194,933,158	164.	192.	273.	43,720,512	23.49	0.122	191.32	0.996
"	1889	"	"				"	11.9	6.72	759,200		759,200	207,809,842	164.	192.	275.	43,830,526	19.49	0.101	150.87	0.784
"	1890	"	"				"	11.9	6.72	836,000		836,000	228,409,473	164.	192.	275.	43,749,696	21.52	0.112	126.05	0.656
"	1891	"	"				Bituminous	14.0	4.87	1,139,600		1,139,600	280,553,052	164	192.	251.	39,421,248	21.09	0.11	115.12	0.60
"	1892	"	"				"	14.0	4.87	1,308,100		1,308,100	336,525,767	164.	190.	260.	40,980,960	18.00	0.10	125.14	0.60
Ware	1888	1886	Town	Collecting Well	Pumping to Reservoir	Deane Steam Pump Co.	Bituminous			296,161		296,161	48,674,280	221.	244.	164.	33,444,379	32.77	0.134	108.51	0.44
"	1889	"	"	"			"			350,220		350,220	60,866,730	221.	244.	174.	35,363,874	29.05	0.119	90.02	0.36
"	1890	"	"	"			"			360,356		360,356	58,880,010	221.	244.	163.	33,250,027	27.06	0.11	93.62	0.38
"	1891	"	"	"			"			411,320		411,320	71,686,150	221.	244.	174.	35,465,926	23.91	0.097	76.31	0.32
"	1892	"	"	"			"			394,678		394,678	70,016,730	221.	244.		36,100,630				
Wellesley	1888	1884	Town	Two Wells	Pumping to Reservoir	H. R. Worthington.	Bituminous	9.0	5.25	232,366	4,900	237,266	42,276,200	250.	278.	182	41,312,220	26.87	0.10	156.27	0.56
"	1889	"	"	"			Bit'ms & Sc'n'gs		5.25, 2.53	372,101	4,864	376,965	71,046,042	250.	278.	188.	43,696,807	29.38	0.105	147.43	0.53
"	1890	"	"	"			"	9.0	5.25, 2.53	488,536	4,238	492,774	93,227,568	250	278.	189.	43,843,624	19.46	0.07	123.77	0.445
"	1891	"	"	"			"	9.0	5.25, 2.53	490,168	3,515	493,683	92,412,000	250.	278.	185.	43,400,111	28.49	0.102	138.59	0.497
"	1892	"	"	"				9.5		459,358	470	459,828	87,424,800	250.	278.	193.	44,080,840	25.39	0.091	130.75	0.47
Woonsocket	1888	1884	Town	Crooks Fall Brook	Pumping to Tank	G. F. Blake Man. Co.	Bituminous	7.8	4.70, 5.17	404,021	374	404,395	76,640,143	239.5	241.4	185.	37,157,203	28.88	0.119	184.60	0.765
"	1889	"	"	"			"	7.6	4.90, 5.15	522,985	457	523,443	102,801,607	243.9	245.7	196.	40,176,620	21.15	0.088	186.45	0.71
"	1890	"	"	"			Bit'ms & Ant.	10.1	4.50, 4.90	594,160	744	617,904	120,844,126	247.41	249.6	195.	36,079,202	27.20	0.109	185.56	0.74
"	1891	"	"	"			Bituminous	7.3	4.50	707,514	463	707,977	132,807,571	248.8	250.2	187.	39,145,128	22.95	0.091	167.84	0.62
"	1892	"	"	"			"	7.0	4.53	770,750	548	771,298	156,644,383	253.5	255.1	203.	43,188,329	19.68	0.076	153.05	0.59

TABLE II.—FINANCIAL.

Statistics for the Years 1888–1892. In Form Adopted by the New England Water Works Association.

Compiled by the Senior Editor.

Name of Place.	Year.	Receipts From Consumers.					Receipts From Public Funds.					K.	AA.	BB.				DD.
		A.	B.	C.	D.	E.	F.	G.	H.	I.	J.							
		Rates, Domestic.	Rates, Manufacturing.	Net Receipts for Water.	Miscellaneous Receipts.	Total Receipts.	Hydrants.	Fountains.	Street Watering.	Public Buildings.	General Appropriation or Miscellaneous.	Gross Receipts.	Management and Repairs.	Interest on Bonds.	Refunded Water Rates.	Total Maintenance.	Bonds Paid.	Balance.
		$	$	$	$	$	$	$	$	$	$	$	$	$	$	$		$
*Boston, Cochituate Works	1888	618,491.50	581,547.11	1,200,038.61	39,588.54	1,239,627.15	86,976.00			30,371.31		1,356,974.56	383,638.16	735,791.40	515.27	1,119,944.83		237,029.63
"	1889	624,825.51	629,613.84	1,254,439.35	27,726.66	1,282,166.01	74,250.00			29,048.95		1,385,464.96	345,986.88	755,268.27	1,873.33	1,103,128.48		282,336.48
"	1890											1,382,422.53	381,147.10	765,079.10	1,293.24	1,147,519.44		234,903.09
"	1891											1,946,446.16	398,755.92					
"	1892											1,518,813.98	392,762.21	810,981.63	963.05			
*Boston, Mystic Works	1888	185,158.57	105,937.47	291,096.04	1,960.41	293,056.45	8,778.00		3,702.13	3,061.05		308,597.63	162,086.42	41,992.50	89,862.73			14,655.98
"	1889	191,546.92	108,724.41	300,271.33	2,047.68	302,318.91	9,410.00		3,398.39	4,117.57		319,244.87	125,660.21	41,642.50	98,131.52			53,810.64
"	1890											332,634.02	144,184.44	42,357.50	101,985.84			44,106.24
"	1891												174,421.92					
"	1892											395,792.47	129,354.49	19,257.50	137,749.55			
Burlington	1888	28,853.45	2,652.55	31,506.00			1,200.00	325.00		69.00		33,100.00	13,766.73	11,191.00		24,957.73		8,142.27
"	1889	28,629.22	2,400.00	31,029.22			1,200.00	325.00		75.00		32,629.22	15,463.58	11,192.00		26,655.58		5,973.64
"	1890	28,926.46	2,763.33	31,689.79			1,200.00	325.00		75.00	1,253.61	34,543.40	16,418.20	11,192.00				6,933.20
"	1891	30,892.42	3,096.77	33,989.19			1,200.00	325.00		75.00	3,545.28	39,134.47	20,055.53	11,263.00				7,815.94
"	1892																	
Fall River	1888			84,931.79	6,954.02						30,000.00	121,885.81	32,787.20	96,970.00				
"	1889			91,741.83	8,224.69						30,000.00	129,966.52	36,984.98	96,640.00				
"	1890			100,141.23	8,793.68						20,500.00	128,434.91	37,206.79	97,375.00				
"	1891			112,930.77	6,926.15						15,000.00	134,856.92	40,378.24	95,705.00				
"	1892			116,369.02	6,634.78						12,800.00	135,803.80	40,933.22	97,420.00				
Fitchburg	1888	26,298.18	7,973.38	34,271.56			12,800.00	900.00	800.00	2,500.00	51.85	50,323.41	12,768.17	27,930.00				9,625.24
"	1889	29,417.26	8,390.58	37,507.84			12,800.00	900.00	800.00	1,500.00		53,507.84	14,129.20	27,930.00				11,448.64
"	1890	32,568.20	9,019.07	41,587.27			12,800.00	900.00	800.00	1,500.00		57,587.27	8,142.49	27,930.00				21,514.78
"	1891	33,621.54	9,303.79	42,925.33			12,800.00	900.00	800.00	1,500.00		58,925.33	9,841.46	29,930.00				19,153.87
"	1892	40,408.37	11,568.12	51,976.49			12,800.00	900.00	800.00	1,500.00	22,899.22	90,875.71	17,653.67	23,930.00				49,292.04
Holyoke	1888			55,677.03			3,000.00			277.80	8,809.99	67,764.82	10,339.59	15,000.00		25,339.59		
"	1889			61,738.70			3,000.00			292.60	20,080.01	85,111.31	9,209.23	15,000.00		24,209.23		
"	1890			63,120.55			3,000.00			298.40	17,038.06	83,457.01	9,908.89	15,000.00		24,908.89		
"	1891			62,607.76			3,000.00			251.12	9,192.70	75,051.58	12,639.30	15,000.00		27,639.30		
"	1892			63,923.21			3,000.00			251.12	8,038.38	75,212.71	11,353.84	15,000.00		26,353.84		
Lynn	1888											140,720.59	26,164.19	67,308.50				
"	1889											146,582.21	21,248.94	73,462.80		95,747.34		
"	1890											162,617.89	22,107.36	81,262.37		103,444.03		
"	1891	116,159.75	29,855.44	146,015.19	1,793.02	147,808.21					20,000.00	167,808.21	30,872.86	82,547.44		113,420.30		
"	1892	127,305.38	39,040.31	166,345.69	2,003.11	168,348.80					20,000.00	188,348.80	28,126.14	69,893.76		98,019.91		90,328.89
New Bedford	1888	44,168.18	5,367.36	49,535.54	348.00	49,883.54					88,300.00	138,183.54	31,248.84	46,300.00			30,000.00	30,634.70
"	1889	49,226.75	6,519.14	55,745.89	273.50	56,019.39					88,400.00	144,419.39	27,091.50	46,400.00			30,000.00	40,927.89
"	1890	52,777.08	9,704.45	62,481.53	205.64	62,687.17					84,900.00	147,587.17	30,701.31	42,900.00			30,000.00	43,985.86
"	1891	57,536.13	8,853.79	66,389.92	368.75	66,758.67					83,000.00	149,758.67	53,824.48	41,000.00			30,000.00	24,934.19
"	1892	64,068.87	7,803.68	71,872.55	351.45	72,227.00					81,700.00	153,927.00	37,761.70	39,100.00			30,000.00	46,465.30
New London	1888			23,575.01									7,174.27	17,500.00		24,674.27		
"	1889			24,605.22									4,972.90	17,500.00		22,472.90		
"	1890			26,767.52									5,338.78	22,140.00		27,478.78		
"	1891			28,313.95									6,085.20	22,140.00		28,225.20		
"	1892			30,702.76							6,500.00		5,341.82	22,140.00		27,481.82		
Newton	1888	46,478.92	2,213.29	48,692.21	3,747.05	52,439.26	10,800.00	1,091.69	2,000.00	1,449.57		67,780.52	13,938.33	42,900.00	258.56			
"	1889	48,671.51	2,625.27	51,296.78	5,519.39	56,816.17	11,320.00	1,045.23	1,797.84	1,147.89	351.81	72,478.94	15,420.78	59,600.00	408.01			
"	1890	51,930.99	3,009.03	54,940.02	4,071.47	59,011.49	12,240.00	1,172.50	1,748.79	1,063.80	89.99	75,326.57	14,794.36	66,840.09	425.62			
"	1891	55,645.29	2,264.92	57,910.21	5,421.05	63,331.26	12,840.00	1,325.00	2,100.00	1,025.77	125.83	80,807.86	13,975.02	74,160.59	293.98			
"	1892	61,849.66	2,419.15	64,268.81	4,849.72	69,118.73	13,000.00	1,438.84	2,200.00	1,115.72	542.73	87,416.02	14,887.98	79,500.00	410.89			
Plymouth	1888	14,294.28	1,551.17	15,845.45	252.03	16,097.48						16,097.48	5,532.20	6,130.00			1,300.00	3,135.28
"	1889	15,472.57	572.72	16,045.29	20.11	16,065.40						16,065.40	4,198.07	6,318.00			1,300.00	4,249.33
"	1890	15,022.79	1,106.09	16,128.88	32.49	16,161.37						16,161.37	4,831.99	5,820.00			4,100.00	1,409.38
"	1891	15,518.64	1,114.50	16,633.14	6.50	16,639.64						16,639.64	5,234.82	5,236.00			4,100.00	2,068.82
"	1892	16,285.05	1,326.00	17,611.05	550.87	18,161.92						18,161.92	6,260.75	5,072.00			4,100.00	2,729.17
Springfield	1888			112,581.21	16,882.66	129,463.87	11,140.00	1,730.00		2,865.10		145,198.97	43,973.82	82,000.00				19,225.15
"	1889			122,541.52	15,915.90	138,457.42	12,020.00	1,818.90		3,047.45	14,000.00	169,343.77	31,953.65	82,000.00				
"	1890			149,913.27	19,946.95	169,860.22	12,160.00	1,789.00		3,240.60	10,000.00		34,799.51	82,000.00				
"	1891			136,985.11	18,462.79	155,447.90	12,580.00	1,878.10		3,351.70	14,960.41		28,073.27	86,375.00				
"	1892			146,349.09	25,239.65	171,588.74	13,340.00	2,034.10		3,366.25		190,329.09	41,978.21	86,375.00				
Taunton	1888	31,231.23	6,583.17	37,814.40	161.68	37,976.08	6,000.00	881.47	800.00	748.50		46,406.05	14,167.95	26,123.00		40,290.95		6,115.10
"	1889	33,331.52	7,398.76	40,730.28	39.20	40,769.48	5,000.00	1,078.37	800.00	832.66		48,480.51	12,618.33	26,423.00		39,041.33		9,439.18
"	1890	31,877.02	8,780.59	40,657.61	20.50	40,678.11	4,000.00	1,079.59	800.00	427.00		46,984.70	13,060.84	27,108.00		40,168.84		6,815.86
"	1891	32,632.06	10,421.25	43,053.31	38.88	43,092.19	4,000.00	1,070.73	800.00	528.49		49,491.41	13,204.97	28,823.00		42,117.97		7,373.44
"	1892	34,683.62	9,803.52	44,487.14	196.38	44,683.52	3,500.00	1,156.02	800.00	511.26		50,650.80	13,881.49	30,343.00		44,227.49		6,423.31
Troy	1888			82,633.25	8,869.81	91,503.06						91,503.06	53,057.18	16,610.00		69,667.18		21,835.88
"	1889	63,064.03	14,140.77	77,204.80	8,305.89	85,510.69						85,510.69	54,674.64	15,847.50		70,522.14		14,988.55
"	1890	63,484.42	22,176.39	85,660.81	6,201.28	91,862.09						91,862.09	37,873.67	15,422.50		53,296.17		38,565.92
"	1891	65,339.97	19,962.00	85,301.97	6,058.06	91,360.03						91,360.03	43,122.75	14,822.50		57,945.25		33,412.78
"	1892	66,480.02	18,861.53	85,341.55	8,169.31	93,510.86						93,510.86	59,368.06	13,885.00		73,253.06		20,257.80
Waltham	1888	33,675.86	2,982.61		2,963.00		3,750.00	340.00		450.00		44,162.13	18,593.22	18,800.00				6,772.91
"	1889	36,292.49	3,101.76		4,297.78		3,960.00	373.00		472.00		48,497.03	12,471.96	19,680.00				16,345.07
"	1890	40,553.50	3,661.99		1,594.89		4,040.83	436.00		559.50		50,846.71	10,029.97	18,746.65				22,070.09
"	1891	43,669.43	5,148.79		1,093.86		4,270.00	460.00		606.50		55,248.58	12,866.62	19,430.00				22,951.96
"	1892	46,395.44	5,363.01		1,979.74		4,380.00	784.08		644.68		59,546.95	12,454.31	18,330.00				28,662.64
Ware	1888			5,099.57		5,099.57	1,100.00	133.54		128.33		6,461.44	2,501.53	2,780.00		5,281.53		
"	1889			5,708.36	94.64	5,803.00	1,000.00	195.89		133.00	131.70	7,263.59	2,797.28	2,682.00		5,479.28		
"	1890			5,603.75	206.79	5,810.54	1,000.00	274.22		133.00	44.25	7,235.01	2,952.18	2,560.04		5,512.22		
"	1891			6,199.63	241.39	6,441.02	1,000.00	310.65		133.00	99.15	7,983.82	3,027.27	2,442.99		5,470.26		
"	1892			7,828.32	321.38	8,149.70	1,000.00	313.00		133.00	319.21	9,914.91	3,145.43	2,305.24		5,450.67		
Wellesley	1888	5,209.60	85.00	5,221.60	104.88	5,330.48	2,140.00	40.00	200.00	50.00	1,600.00	9,720.48	2,971.08	3,640.00				3,109.40
"	1889	6,370.94	89.18	6,460.12	87.60	6,547.72	2,520.00	400.00	200.00	50.00	1,100.00	10,817.72	3,934.56	6,540.00				
"	1890	8,786.31	85.00	8,871.31	487.16	9,358.47	2,680.00	400.00	200.00	50.00	360.00	13,048.47	4,938.98	6,600.00				
"	1891	8,629.70	199.70	8,829.40	601.63	9,431.03	3,100.00	400.00	200.00	62.39		13,193.42	4,772.95	7,320.00				
"	1892	9,420.26	411.99	9,832.25	309.62	10,141.87	3,060.00	400.00	200.00	84.43		13,886.30	3,870.85	7,560.00				
*Woonsocket	1888	10,118.26	1,334.75	11,453.01	159.30	11,612.31	8,096.25	1,173.68	305.81	126.38	4,399.29	25,713.72	4,889.87	8,888.76				11,935.09
"	1889	10,720.53	1,352.86	12,073.39	375.31	12,448.70	8,523.75	1,297.68	431.99	184.84	7,857.68	30,744.64	6,849.74	12,327.77				11,567.13
"	1890	16,849.02	1,943.68	18,792.70	199.53	18,992.23	12,130.00	1,462.27	895.70	280.25	8,356.79	42,117.24	8,331.07	14,092.80				19,693.37
"	1891	18,473.73	2,823.55	21,297.28	195.84	21,493.12	12,835.00	1,214.96	1,107.17	292.79	8,949.27	44,992.31	8,137.53	14,153.57				22,701.21
"	1892	20,604.31	4,356.27	24,960.58	116.56	25,077.14	13,277.50	1,300.67	2,496.23	386.51	8,869.24	51,407.29	8,943.08	15,132.71				27,331.50

*Woonsocket figures for 1888 are for 8 months only.
Boston " " 1891 " 13 "

TABLE III.—CONSUMPTION.

Statistics for the Years 1888-1892. In Form Adopted by the New England Water Works Ass'n.

Compiled by the Senior Editor.

Name of Place.	Year.	1. Estimated Population. Total at date.	2. On line of pipe.	3. Supplied at date.	5. Quantity used through domestic meters, gallons.	6. Quantity used through manufacturing meters, gallons.	Percentage of total consumption, metered.	7. Average daily consumption, in gallons	8. Gallons per day. Each inhabitant.	9. Each consumer	10. Each tap.
Boston (Cochituate Works)	1888	378,600		370,000	393,970,000	2,477,262,500	23.6	33,310,700	88.	90.	585
"	1889	387,600		380,000	308,040,000	2,655,322,000	25.3	32,070,000	82.7	84.4	545
"	1890	410,600		405,000	318,840,000	2,978,872,500	26.7	33,871,700	82.5	84.7	558
"	1891	422,100		417,000	3,717,945,000		27.	37,686,900	89.3	90.4	599
"	1892	433,600			4,108,687,500		27.2	41,312,400	95.3		635
Boston (Mystic Works)	1888	108,000		106,000	3,804,318	461,977,300	15.4	8,258,400	76.5	77.9	469
"	1889	111,200		110,000	4,432,000	480,842,000	17.1	7,830,500	70.4	71.2	423
"	1890	117,700		115,000	6,978,400	554,178,300	18.5	8,301,400	70.6	72.1	425
"	1891	121,200		120,000	673,625,900		20.4	9,055,200	74.7	75.5	440
"	1892	124,800			681,577,500		19.	9,810,800	78 6		454
Burlington	1888	16,000	14,200	13,700	28,253,200	12,953,250	16.4	696,877	45.	50.	286
"	1889	16,000	14,200	13,700	28,331,402	12,877,910	16.	705,639	44.	50.	281
"	1890	14 590	14,300	14,000	40,957,500	7,041,000	17.	765,400	52.	55.	300
"	1891	14,450	14,450	14,150	42,133,875	16,170,000	19.5	817,809	55.	58.	314
"	1892						20.	789,289			
Fall River	1888	63,696		60,524			38.1	1,768,524	27.8	29.2	401
"	1889	68,774		64,000			39.5	1,877,937	27.3	29.3	400
"	1890	74,918		69,000			38.5	2,136,182	28.5	31.0	429
"	1891	77,329		71,000			40 2	2,355,700	30.5	33.2	449
"	1892	83,026		76,000			43.	2,285,948	27.5	30.1	414
Fitchburg	1888	22,000	20,000	15,500	21,744,057	119,600,700	29.8	1,300,000	57.	84.	529
"	1889	23,000	20,500	16,740	25,677,743	120,435,100	30.4	1,316,000	56.	78.	490
"	1890	22,007	19,500	16,000	32,768,371	125,000,000	31.1	1,425,000	65.	89.	491
"	1891	25,000	22,500	17,000	36,228,000	130,193,000	29.2	2,355,700	62.	88.	502
"	1892	27,500	25,000	21,000	43,617,000	153,681,000	27.	2,285,948	72.	95.	593
Holyoke	1888	33,229	32,729	32,429	178,684,500			2,381,190	72.	73.	1,042
"	1889	34,728	34,228	33,928	192,327,700			2,482,393	72.	73.	1,012
"	1890	35,637	35,137	34,837	197,396,250			2,548,045	71.5	73.	986
"	1891	36,114	35,614	35,114	208.645,500			2,717,721	75	77.	1,011
"	1892	38,500	38,000	37,500	209,300,250		19.2	2,979,689	77.7	79.4	1,054
Lynn	1888	55,529		50,256	100,308,150			2,474,556		49.2	
"	1889	58,882		56,099	121,930,400		13.6	2,450,413	41.6	43.7	284
"	1890	59,400		56,430	124,620,000		12.8	2,656,690	44.7	47.1	289
"	1891	62,500		59,400	149,275,000			3,131,352		52.7	
"	1892	67,000		64,700	209,245,000		16.1	3,549,293		54.8	
New Bedford	1888	37,500	33,550	31,826	4,286,394	157,904,641	13.35	3,319,707	88.	104.	574
"	1889	40,000	36,500	34,000	8,190,944	259,690,821	20.6	3,554,908	89.	105.	582
"	1890	41,500	37,500	35.740	9,088,313	359,034,506	24.6	4,066,200	98.	114.	636
"	1891	45,000	40,000	38,500	9,914,205	327,846,754	22.65	4,145,648	92.	108.	615
"	1892	50,000	45,000	41,776	9,588,881	272,550,829	17.6	4,393,320	88.	105.	616
New London	1888	13,500	11,750	9,775				1,342,000	99.2	137.	731
"	1889	14,000	12,500	10,500				1,378.000	98.4	131.	713
"	1890										
"	1891										
"	1892	14,000	13,800	12,600				1,169,171	83.5	92.	495
Newton	1888	23,500	22,500	22,000	102,100,000	12,800,000	44.9	708,491	29.8	31.5	177
"	1889	23,500	22,500	22,000	129,500,000	17,130,000	47.1	853,435	36.	38.	203
"	1890	25,000	24,000	23,500	139,200,000	22,100,000	44.8	985,396	39.4	42.	222
"	1891	26.000	25,200	24,700	151,800,000	13,300,000	42.4	1,067,294	41.	43.2	227
"	1892	27,300	26,500	26,000	175,000,000	15,100,000	40.4	1,288,000	47.	49.5	258
Springfield	1888	41,000	35,300	30,500	116 698,858		8.	4,000,000	97.	131.	777
"	1889	44,000	36,500	31,500	147,226,233		10.	4,000,000	91.	127.	728
"	1890	44,164	37,000	32,000	169,646,406		11.62	4,000,000	90.	125.	693
"	1891	45,460	38,500	33,500	189,304,641		12.93	4,010,986	88.	120.	649
"	1892	49,300	42,000	36,500	212,454,760		13.57	4,289,013	87.	102.	646
Taunton	1888		22,800	20,100	34,132,833	67,043,045	36.8	751,882	32.	37.	248
"	1889		22,900	20,700	32,432,212	81,966,873	40.7	769,551	32.	37.	244
"	1890		23,000	20,800	37,276,077	82,843,716	41.3	796,716	31.	38.	245
"	1891	25,448	23,210	21,320	42,500,703	96,256,675	37.1	1,022,211	40.	48.	302
"	1892		23,380	21,870	51,305,470	90,802,061	38.3	1,012,168	40.	46.	286
Troy	1888	60,000	51,368	45,700	46,329,573		1.5	8,000,000	137.	160.	1,523
"	1889	60,000	51,368	46,000	280,753,287		9.9	7,839,835	130.	170.	1,369
"	1890	60,650	56,000	56,000	336,735,537		12.2	7,608,468	125.	136.	1,315
"	1891	65,000	60,000	58,000	324,220,168		10.9	8,173,513	125.	141.	1,372
"	1892	65,000	60,000	58,000	357,121,000		11.1	8,240,788	127.	142.	1,122
Waltham	1888	18,000	17,000	16,200	11,619,289		6.	534,063	29.7	32.9	243
"	1889	19,800	18,600	18 000	12,076,335		6.	569,342	29.	31.6	242
"	1890	19,000	18,200	18,000	14,043,675		6.1	625,779	33.	34.4	251
"	1891	20,000	19,000	18,800	21,041,072		7.5	768,638	38.3	40.9	290
"	1892	21,000	20,000	19,500	24,929,792		7.4	921,998	43.9	47.3	323
Ware	1888	7,800	6,500	4,500	4,078,585	6,362,373		133,359	17.	31.	365
"	1889	7,500	6,500	4,500	8,881,625	4,990,906		166,758	22.	37.	412
"	1890	7,315	6,500	4,500	14,552,314	5,500,222		161,096	22.	36	349
"	1891	7,315	6,550	5,000	13,863,032	7,183,971		196,400	27.	39.	375
"	1892				25,733,913			191,576			
Wellesley	1888	3,400	2,500	1,726	7,055,937	96,330	19.	138,156	40.	80.	335
"	1889	3,500	2,650	2,450	10,277,198	136,725	16.	194,646	55.	79.	408
"	1890	3,590	3,340	2,650	12,3 2,637	375,292	13.6	255,418	70.	91.	507
"	1891	3,590	3,379	2,795	14,467,238	459,000	16.1	253,183	70.	91.	464
"	1892	3,625	3,400	2,866	10,447,125	1,029,247	13.1	239,520	66.	83.	410
Woonsocket	1888	20,000	16,750	10,500	29,725,947	5,610,670	35.9	269,528	13.	25.7	313
"	1889	20,000	17,150	11,000	29,675,832	8,738,836	37.7	302,310	15.	27.5	307
"	1890	22,000	20,000	15,000	70,393,244		58.5	326,455	15.	21.8	293
"	1891	22,000	20,000	15,000	79,217,992		52.5	360,538	16.4	24.	282
"	1892	24,500	22,000	18,000				423,562	17.3	23 5	301

TABLE IV—DISTRIBUTION.

Statistics relating to MAIN PIPES for the Years 1888—1892. In Form Adopted by the New England Water Works Assossociation.

Compiled by the Senior Editor.

Name of Place.	Year.	1. Kind of pipe used.	2. Size of distribution pipe in inches.	3. Distribution extended during year.	4. Distribution discontinued during year.	5. Total length of distribution pipe in use. Miles.	6. Cost of repairs per mile.	7. No of leaks per mile.	8. Length of dis'bution less than 4in. Miles	9. Hydrants. Number added.	10. Hydrants. Total in use.	11. Stop gates. Number added.	12. Stop gates. Total in use.	15. Range of pressure at center. Day and night.
Boston (Cochituate Works.)	1888	Cast iron.	4" to 48"	122,624	16,030	456.7	$			118	5,008	249	4,882	35 to 75
"	1889	"	"	133,754	12,081	479.7				177	5,285	249	5,147	"
"	1890	"	"	105,835	5,725	498.7				173	5,458	265	5,412	"
"	1891	"	"	111,178	5,258	519.0				247	5,684	289	5,691	"
"	1892	"	"	94,460	4,270	536.0				148	5,834	219	5,910	"
Boston (Mystic Works.)	1888	Cast iron and wrought iron cement lined.	3" to 30"	35,809	12,641	141.5			5.5	21	956	71	1,379	
"	1889		"	42,023	10,425	147.5			5.5	43	999	83	1,462	
"	1890		"	39,923	3,898	152.3			5.4	73	1,074	113	1,575	
"	1891		"	53,768	22,357	158.			5.5	65	1,116	114	1,689	
"	1892		"			160.4			5.5	107	1,223	110	1,799	
Burlington	1888	Wrought iron, cement lined; wrought iron; cast iron.	½" to 10"	6,387	3,714	30.09	10.38	.3		1	163	3	266	70 to 85
"	1889		"	4,902	3,224	30.4	7.89	.7	5.	1	164	9	275	"
"	1890		½" to 16"	860	420	30.4	7.89	.5		1	164	11	278	"
"	1891		"	10,837	6,074	31.4	3.20	.35		8	172	60	325	"
"	1892					31.6					172	22	347	
Fall River	1888	Cast iron.	6" to 24"	8,692		61.4				12	625	11	626	80
"	1889	"	"	6,300		62 5				9	634	13	639	80
"	1890	"	"	5,540		63.6				8	642	8	647	80
"	1891	"	"	6,267		64.8				7	649	12	659	80
"	1892	"	"	9,590		66.6				15	664	15	674	80
Fitchburg	1888	Wrought iron cement lined and cast iron.	2–16	12,346		38.14	Cement, 81 20 CastIron, 2.05		2.08	12	268	24	254	High service. 155—160 Low service. 75—80
"	1889		2—16	8,591		41.1	7.55		2 39	13	281	15	269	
"	1890		2—16	14,366		43 7	9.56		1.83	16	297	15	295	
"	1891		2—16	6,793		42.9	6.22		1.96	19	314	58	353	
"	1892		2—30	36,815		50.2	5.77		1.96	16	330	32	385	
Holyoke	1888	Wrought iron and Cast iron.	½" to 20"	16,579	2,917	45.	14.14			14	288	35	333	45—100
"	1889		"	8,193	108	46.5	4.95			13	301	20	353	"
"	1890		"	13,674		49.2	6.65			14	315	21	374	"
"	1891		"	6,836		50 5	3.91		5.3	19	455	22	396	"
"	1892		"	7,040		51.8	3.66		5.3	15	487	20	418	
Lynn	1888	Wrought iron cement lined and cast iron.	4—16	9,389		82.9				12	602	27	713	54—65
"	1889		4—16	22,877		87.3				19	620	39	752	54—65
"	1890		"	24,811		92.				38	658	52	801	"
"	1891		"	35,554		98.7				47	705	53	854	50—65
"	1892		2—20	23,944		103.2				42	747	38	892	"
New Bedford	1888	Wrought iron cement lined and cast iron.	4" to 30"	25,469	1,586	59.2	14.66		1.1	35	445	68	615	31—40
"	1889		"	15,685	6,049	61.1	20.00		1.1	15	460	28	643	30—36
"	1890		"	12,715	4,901	62.5	17.87		1.2	17	477	26	669	"
"	1891		"	16,018	3,657	64.9	22.47		1.1	23	499	32	701	"
"	1892		"	20,689	866	68.6	9.94		1.1	43	542	41	742	"
New London	1888	Wrought iron cement lined and cast iron.	4" to 16"	2,392	0	26.2	55.42	6.3	1.9	1	137	7	113	27—54
"	1889		"	3,744	0	27.	21.14	1.8	1.7	2	139	8	121	25—54
"	1890		4" to 20"	39,554	4,256	33.6	15.89	3.	2.	9	148	28	149	45—54
"	1891		"	12,033	737	34.6	32.16	1.6	2.2	8	156	17	166	45—50
"	1892		"	12,156	2,214	38.2	20.08	1.2	2.5	6	162	18	184	45—50
Newton	1888	Cast iron.	4" to 20"	19,918		86.8	10.73		2.4	42	588	23	427	60
"	1889	"	"	17,786		90.2	10.77		2.4	21	606	24	451	60
"	1890	"	"	17,984		93.6	6.95		2.5	36	642	24	475	69
"	1891	"	"	45,828		102.0	10.08		2.6	34	676	40	515	84
"	1892	"	"	14,570		105.0	11.72		2.7	28	704	19	534	84
Plymouth	1888	Wrought iron cement lined.	2—20	5,531	520	28.2						25	242	
"	1889		"	2,578	350	28.7	8.44		7.7		83	16	258	
"	1890		"	2,636	816	29.0	8.44		7.7	2	93	9	267	
"	1891		"	1,625		29 2	6.89		7.7	1	94	6	274	
"	1892		"	14,728		32.	6.49		9.5	7	101	13	287	
Springfield	1888	Wrought iron, wrought iron cement lined, and cast iron.	1" to 24"	34,919	16,896	85.		1.01		29	557	54	777	H. S., 90-120. L. S., 30-35
"	1889		"	36,821	4,419	91.1		.65		44	601	101	878	" "
"	1890		"	24,185	17,944	92.3		1.26		7	608	114	992	" "
"	1891		"	25,916	12,299	94.9		.44		21	629	48	1,040	" "
"	1892		"	31,207	11,308	98.6		.40		38	667	84	1,124	H. S., 80-115. L. S.,30-35
Taunton	1888	Cast iron.	4—20	1.12 miles		55 9	37.0		.8	12	487	9	356	Ordinary, 45—50 Fire, 95—100
"	1889	"	"	3.43 "		59.3	24 06		.8	27	514	22	378	
"	1890	"	"	2.06 "		61.3	21.17		.8	22	536	21	399	
"	1891	"	"	4.72 "		66 1	18.10		1.1	40	576	25	424	
"	1892	"	"	1.76 "		67.8	19.92		1.2	47	623	7	431	
Troy	1888	Cast iron.	4—30	3,472	150	53.5	11.08		.7	29	629	20	913	High Service. 25—75 Middle Service, 25—115 Low Service, 35—60
"	1889	"	"	2,727		55.7	7.93		.7	34	661	33	1,010	
"	1890	"	"	4,473		55.8	4.89		.7	23	684	44	1,054	
"	1891	"	"	5,221		56.9	2.29		.7	12	696	53	1,107	
"	1892	"	"	4,535		57.7	7.10		.6	19	717	35	1,142	
Waltham	1888	Wrought iron cement lined, cast iron.	2—24	14,148		36.4	8.87			9	197	52	349	55
"	1889			11,250		37.7	12.40	.37		3	200	23	372	"
"	1890			6,359		38.9	7.50	.05		11	211	27	399	"
"	1891			15,610		41.9	26.38	2.05		7	218	37	436	"
"	1892			15,305		44.4	25.83	1,4		14	232	39	475	"
Ware	1888	Cast iron.	4" to 12"	1,845		7.75		.2		4	56	3	75	85
"	1889	"		2,853		8.25		.2		3	59	3	78	"
"	1890	"		1,048		8.45		.2		2	61	2	80	"
"	1891	"		830		8.6		.2		1	62	1	81	"
"	1892	"		1,802		9.0		.2		3	65	5	86	"
Wellesley	1888	Cast iron.	4—12	11,316		19.7	6.25	.6	.4	23	126	11	113	70
"	1889	"	"	5,308		20.7	2.02	.6	.4	8	134	10	127	"
"	1890	"	"	7,436		22.1	1.00	.4	.4	11	145	11	138	"
"	1891		"	7,659		23.6	1.65	.5	.4	8	153	12	150	"
"	1892	"	"	828		23.8	1.35	.6	.5	8	161	2	152	"
Woonsocket	1888	Cast iron.	4—14	6,310		23.5	1.21			15	349	20	263	90—120
"	1889	"	"	11,080		25.6	3.67	1.19		28	377	24	287	90—115
"	1890	"		10,576		27.6	3.98	.79		26	403	20	307	"
"	1891	"	4—20	20,062		31.4	.75	1.26		38	441	48	355	"
"	1892	"	4—20	29,650		37.00	2.68			14	455	38	393	"

TABLE V—DISTRIBTUION.

Statistics relating to SERVICE PIPE for the Years 1888—1892. In Form Adopted by the New England Water Works Association.

Compiled by the Senior Editor.

Name of Place.	Year.	16. Service pipe. Kind of pipe used.	17. Size of pipe in inches.	18. Length of pipe extended	19. Length of pipe discontinued.	20. Total length now in use, miles.	21. Service taps. Number added.	22. Service taps. Total in use.	23. Av. length of service.	24. Average cost of service.	25. Meters. Number added.	26a. Meters. Now in use. Domestic.	26b. Meters. Now in use. Manufact'y.	27. Motors and elevators. Number added.	28. Motors and elevators. Total in use.
Boston (Cochituate Works)	1888	Lead and cast iron.	½" to 4"	50,974	2,768		1,712	56,947		$		3,133			399
"	1889		"	58,768	6,817		1,863	58,810			342	3,456			426
"	1890		½" to 6"	61,800	4,606		1,908	60,718			172	3,627			451
"	1891		"	69,859	5,635		2,159	62,877			212	3,839			518
"	1892			59,807	5,871		2,197	65,074			73	3,912			
Boston (Mystic Works)	1888		½" to 2"	24,155		95.7	798	17,607				387			8
"	1889			18,527		100 7	920	18,527				386			27
"	1890			20,360		104.[illegible]	993	19,520			5	391			23
"	1891			28,695		110.1	1,036	20,556			15	406			21
"	1892			31,584			1,032	21,588			29	435			
Burlington	1888	Galvanized iron and lead.	½" to 4"	3,046	116	13.5	105	2,433	31.	11.09	71	409	36	1	8
"	1889		"	2,538	100	14.	82	2,513	31.	7.80	80	486	39	2	10
"	1890		"	904	45	14.13	38	2,549	22.	7.75	59	541	43	6	16
"	1891		"	1,554	74	14.41	61	2,609	29.	8.15	70	605	49	1	17
"	1892		"				57	2,666			57				
Fall River	1888	Lead.	½" to 2"				215	4,412			197	3,138			13
"	1889		"				286	4,698			290	3,428			13
"	1890		"				282	4,980			289	3,717			13
"	1891		"				267	5,247			258	3,975			14
"	1892		"				279	5,526			277	4,252			12
Fitchburg	1888	Wrought iron, cement lined and cast iron.	¾" to 8"	15,745		29.86	253	2,456	62.	9.92	117	571	86	3	18
"	1889		"	13,805		32.47	228	2,684	60.	13.09	144	695	98	12	30
"	1890		"	10 308		33.78	221	2,905	46.	13 49	169	792	160	2	32
"	1891		"	6,469		35.65	198	3,193	33.	9.53	159	1,000	111	5	37
"	1892		"	13,856		38.27	266	3,369	48.	6.42	156	1,162	195	7	42
Holyoke	1888	Cement lined wrou't iron	⅝" to 4"	2,240		8.7	112	2,2[illegible]5	20.	11.94		143		2	56
"	1889	Rubber " " "	"	3,500		9.3	178	2,454	20.	10.23		145			39
"	1890	Enam'ld " " "	"	2,940	17	9.8	146	2,583	20.	14.56	4	149			38
"	1891	Cast iron.	"	2,977	19	10.3	104	2,687	20.	14 56	6	155			38
"	1892		"	2,820		10.9	141	2,830	20.	14.56	22	177			38
Lynn	1888	Cement lined, wrought iron; adamanta; galvanized iron.	¾" to 6"	22,110		62.3	433	8,233			18	254			
"	1889		¾" to 6"	24,079		66.9	373	8,606			70	324			
"	1890		¾" to 10"	27,338		72.1	573	9,178			16	340			
"	1891		"	31,868	4,275	80.2	556	10,026			43	413			
"	1892		"	29,212	7,350	85 3	567	10,588			81	494			
New Bedford	1888	Lead and cast iron.	½" to 8"	12,753		34.2	291	5,785	43.8	20.42 3 26	8	63	45	1	27
"	1889		"	16,346		37.3	320	6,104	51.1	22 89 12.76	16	68	52	4	31
"	1890		"	9,560		39.1	290	6,394	33.	19.70 1.50	3	76	47		30
"	1891		"	11,525	265	41.3	348	6,742	33.	18.10	12	83	52	3	33
"	1892		"	13,850	102	43.9	397	7,134	35.	15.52	9	91	53		31
New London	1888	Lead, wrought iron cement lined, cast iron and galvanized.	½" to 4"	1,581	129	6.4	87	1,833	18.4	11.88	0	37		5	18
"	1889		"	2,213	120	6.8	131	1,934	18.3	10.98	2	39			18
"	1890		"	3,146	466	7.6	153	2,087	20.5	13.80	4	43			18
"	1891		"	2,966	110	8.1	156	2,235	19.	12.68	7	50		5	23
"	1892		"	2,575	32	8.6	128	2,362	18.6	11.26	80	129		2	25
Newton.	1888	Lead, wrought iron and cast iron.	½" to 4"	10,378		48.2	211	3,978	64.	26.17 12.74	145	2,496	10	2	9
"	1889		"	12,892		50.7	225	4,203	63.6	26.50 12.85	209	2,692	16	3	12
"	1890		"	11,795		52.9	237	4,410	62.9	25.66 12.42	311	2,977	18	2	16
"	1891		"	14,355		55.6	265	4,705	62.4	29.42 13.84	284	3,251	18	1	16
"	1892		"	15,892		58.6	300	5,002	61.8	29.14 15.68	321	3,566	21		16
Plymouth	1888	Wrought iron cement lined and lead.	½" to 1"				47	1,364							
"	1889		"	500		5.	25	1,389	20.	5.92					2
"	1890		"	242		5.2	30	1,415	19 3	5.60					2
"	1891		"	398		5.2	43	1.454	19.3	5.39					2
"	1892		"	343		5.3	49	1,509	18.5	3.80					1
Springfield	1888		½" to 4"				328	5 147			84	556		15	114
"	1889		½" to 4"				350	5,497			195	751		9	123
"	1890		½" to 4"				273	5,770			177	928		17	140
"	1891		"				411	6,181			198	1,126			140
"	1892		½" to 6"				452	6,633			276	1,402		6	146
Taunton	1888	Cement lined wrought iron.	¾" to 3"	miles. 1.59	129	29.4	160	3,027		17.77 7.82	76	795	63		7
"	1889		"	0.94	2,259	30.3	118	3,143		16.11 6.71	80	863	85	1	8
"	1890		¾" to 3"	1.39		31.7	129	3,253		24.14 13.54	52	901	89	1	9
"	1891			1.26		33.	137	3,386		18.43 9.03	69	968	91	2	13
"	1892			1.29		34.25	138	3,507		24.20 15.11	72	1,036	95		13
Troy	1888	Lead and cast iron.	½" to 6"				203	5,453	3.		11	58		2	100
"	1889						214	5,654			165	223			
"	1890						132	5,786			3	226			
"	1891						174	5,969			9	228			
"	1892						324	6,281			9	237			
Waltham	1888	Wrought iron, cement lined and cast iron.	¾" to 6"	7,978	136	23.4	167	2,197	48.	11.50	4	27		2	10
"	1889			13,723	1,136	25.8	156	2,339	78.	26.3	6	34			10
"	1890			11,303	254	27.9	167	2,489	74.	40.57	6	40			10
"	1891			9,095	402	29.8	176	2,650	47.5	30.60	6	46		1	11
"	1892			8,802	100	31.1	172	2,820	50 6	26.50	13	59			11
Ware	1888	Wrought iron cement lined.	1" to 2"			4.35	57	350	53 8		49	76	11		3
"	1889					5.15	40	381	57.5		91	167	11		3
"	1890					5.77	58	430	56.4		34	199	13	1	4
"	1891					6.43	60	490	56.4		32	230	14	1	5
"	1892						49	542			55	291			
Wellesley	1888	Wrought iron, cement lined and lead.	½" to 2"	5,890			53	412	111.		17	65	1	1	1
"	1889		"	4,212			53	465	79.	22.40	17	82	1		1
"	1890		"	2,992			38	503	79.	17.87	10	92	1		1
"	1891		"	4,841			43	546	115.	54.48	14	106	1		1
"	1892		½" to 4"	4,506		9.3	39	584	122.	21.31	57	160	4	1	2
Woonsocket	1888	Lead.	⅝" to 1¼"	1,615		2.6	100	861	15.8	13.13	87	743	18		1
"	1889		⅝" to 1¼"	1,829		3.	122	983	15.5	11.18	93	802	25		1
"	1890		⅝" to 4"	2,160	12	3.4	135	1,117	16.2	10.99	97	897	27	1	2
"	1891		"	2,073		3.8	148	1,276	14.	9.64	117	1,013	27	1	3
"	1892		⅝" to 6"	3,013		4.3	191	1,467	16.5	11.44	110	1,120	31	2	5

OBITUARY.

AUGUSTUS W. LOCKE.—Died at North Adams, Mass , Sunday May 14th, 1893. Age 46 years. Joined this Association June 13, 1889.

He served in the Navy during the war and after his discharge took up the study of civil engineering. After preliminary work he was appointed assistant engineer on the Hoosac tunnel, serving in that capacity from 1868 to 1876. He served as engineer of maintenance of way on the Troy and Greenfield road until 1878 when he was appointed by Governor Long manager and chief engineer of the Troy and Greenfield road and of the Hoosac tunnel. He held his position until 1887 when the road and tunnel were sold to the Fitchburg Co. When he retired he received public commendation through Governor Robinson for his able management of affairs. He then entered upon private business and at the time of his death was chairman of the special commission of the state board on the abolition of grade crossings. Contributed an article to the Journal of September, 1890, entitled "Notes Made in Holland in 1887."

DATE DUE
